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Wire-Bond Electrical Connections:
Testing, Fabrication
and Degradation—
A Bibliography 1957-1971

U.S.
DEPARTMENT
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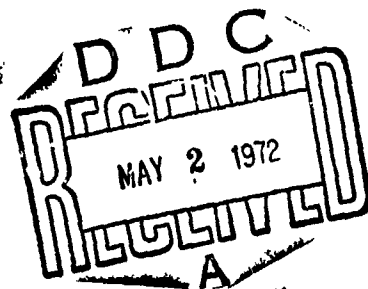
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**Wire-Bond Electrical Connections:
Testing, Fabrication and Degradation--
A Bibliography 1957-1971**

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Wire-Bond Electrical Connections: Testing, Fabrication and Degradation - A Bibliography 1957-1971

Harry A. Schafft

More than 245 papers relevant to wire-bond type electrical interconnections used in microelectronic and low-power discrete and hybrid devices are listed together with key words. The bibliographic search concentrated on compiling papers which appeared in the period from 1965 to 1970, inclusive. The selection of papers was generally limited to those that were pertinent to wire bonds where the wire diameter is less than about 50 μm (2 mils) and where the wire is bonded by either thermocompressive or ultrasonic means. Two indexes are provided: (1) an Author Index and (2) a Key Word Index. The latter includes a tabulation of the literature citations.

Key Words: bibliography; degradation (wire bond); discrete devices; electrical interconnection; fabrication (wire bond); failure (wire bond); hybrid circuits, integrated circuits; microelectronics; reliability; testing (wire bond); wire bond.

1. Introduction

Small-diameter ($< 50 \mu\text{m}$) wire is the principal means of making electrical connections (1) between the semiconductor die and the terminus leading outside the package of microelectronic and low-power discrete and hybrid devices, and (2) between different dice on a single device header of hybrid circuits. This *electrical interconnection* or *wire-bond*,* as it will be referred to here, is considered to be the wire between two bonded points, the bonds, the bonding surface films, and the underlying material in the immediate vicinity of the bonds. *Failure* of a wire bond is one of the principal failure modes in these devices. As a result, great importance has been attached to the following three subject areas: (1) methods for testing and evaluating wire bonds, (2) optimization of the fabrication processes for making wire bonds, and (3) mechanisms of degradation and failure of wire bonds.

This bibliography is a *compilation* of more than 245 published articles, U. S.

government reports, U. S. patents, and conference presentations relevant to wire bonds in these three subject areas of testing, fabrication, and degradation.

The *selection of papers* is generally limited to those that are pertinent to wire bonds that have wire diameters of less than about 50 μm (2 mils) and are bonded by either thermocompressive or ultrasonic means. This is the class of wire bonds that is of most interest in microelectronics. An attempt was made to make the collection of papers on test and evaluation methods complete while the collection of articles in the area of fabrication and degradation is meant to be representative. Some interesting papers could not be included because of restrictions on their distribution. It is quite possible that some papers which should have been included were overlooked. The compiler would appreciate having such omissions called to his attention.

Acknowledgement

The author is pleased to acknowledge the significant contributions made by Elaine C. W. Cohen who assisted in collecting much of the material and performed both expeditiously and cheerfully many of the tedious labors that the compilation of such a bibliography requires. Thanks also go out to Kathryn O. Leedy, Frank R. Kelly, Terry A. Schultz and especially to Ruth E. Joel for assisting in various stages of the preparation of the bibliography; to Kaye E. Dodson for typing the final draft with such dispatch; and to W. Murray Bullis, Frank F. Oettinger, and George J. Rogers for their assistance with various aspects of the format.

This work was performed under the Joint Program on Methods of Measurement for Semiconductor Materials, Process Control, and Devices and was supported in part by the National Bureau of Standards, the Defense Nuclear Agency, and the U.S. Navy Strategic Systems Project Office.

* Certain words or phrases are printed in script to assist in scanning.

2. Bibliography Format, In Brief

The two entries shown on the next page are used to indicate the various elements of the format which are encircled and numbered. The numbers refer to the explanatory notes listed below. A more complete description of the organization and format is given in Appendices A thru D.

Explanatory Notes:

1. *Identification code* for entry. The first two digits give the year of publication; the letter is the initial of the first author's surname; the last digit serves to distinguish entries which have the same first three alphanumeric. Entries are arranged in the bibliography (pp. 21-48) according to these codes.
2. *Author(s)*, editor(s), or organization (if no name(s) are provided). For *Author Index*, see page 4.
3. *First-level key word*[†] for general subject area. First-level key words are capitalized for identification purposes.
4. *Descriptors*^{††} to identify the kind(s) of wire bond(s) pertinent to or described under the subject of the first-level key word (in this example, DEGRADATION).
5. *Second-level key word*[†] to narrow the subject area of the first-level key word above it (in this example Mechanism modifies DEGRADATION). The first letter of a second-level key word is capitalized.
6. *Third-level key word*[†] to modify the second-level key word at its left (in this example intermetallics modifies Mechanism). All the letters are in lower-case. Some third-level key words include words in parentheses.
7. *Order* of first-level key words for subject area indicates the relative emphasis or importance given the respective areas in the entry. In this example, the main subject is degradation with test and fabrication following in that order.
8. *First-level key word* indicating approach or type of entry. Only one such key word is used per entry and it is listed last.
9. *Reading priority* is suggested by underlining the identification code and the appropriate key word(s) of those entries that are of such relative importance in a particular area that they should be seen first. The codes for these entries are also underlined in Section 4B (pp. 12-20).
10. *Title*
11. *Source*. See Appendix B (p. 49) and Table 1 (p. 50) for sources used. See Table 2 (p. 51) for *abbreviations* used for journals and conferences.
12. *Availability note* refers to an address listed in the Appendix. If the number is in brackets the address is one to which an order may be placed for a copy of the entry; if it is in parentheses the address is that of the first author's place of work at the time of publication.
13. *Availability note*. When the report citation is followed by a number preceded by the letters AD or PB, or by the letter N, the report is available from the National Technical Information Service (NTIS), Sills Building, 5285 Port Royal Road, Springfield, Virginia 22151 by using this NTIS accession number when ordering.
14. In some entries, additional *guidance* is provided in brackets. For example, reference may be made to the pages in the paper that are relevant to the subject.

[†] The three levels of *key words* indicating subject area are listed in alphabetical order in Section 4A (pp. 8-11). Page numbers are provided to assist in locating these key words in Section 4B (pp. 12-20) where they are ordered by subject: test, fabrication, and degradation. With each key word in Section 4B is a tabulation of literature citations (using their identification codes). In both Sections 4A and 4B, each key word that may require additional definition is followed by an *explanatory phrase in brackets*. An exception is made for the test method key words. Key words for the test methods are listed in alphabetical order in Table 4 (p. 54) with a brief description for each method. The descriptions are oriented to their function in testing wire bonds.

^{††} *Descriptors* are listed in Section 4B (pp. 12-20) with a tabulation of literature citations.

- 1 — (67P1) Parker, C. D.
INTEGRATED SILICON DEVICE TECHNOLOGY } 10
- 2 — VOLUME XV RELIABILITY
Contract No. AF 33(615)-8306,
May 1967. (AD 655082) (see pp. 35-65) 14
- 3 — (DEGRADATION) bond: TC, US; wire: Al, Au;
film: Al, Au, Au/Mo; substrate: FeNiCo,
Si 13
Stress: process; thermal
Part: bond
- 5 — (Mechanism) contamination; (intermetallics) 6
Failure Rates
- 7 — (TEST)
Screening Procedures
(FABRICATION) bond: TC, US; wire: Au, Al;
film: Ag, Ag/Cr, Al, Au, Au/Mo;
substrate: Si
Evaluation: metal systems; metallization; wire
Procedure
- 8 — (REVIEW)

- 9 — (68A3) Anderson, J. H., Jr. and W. P. Cox
AGING EFFECTS IN AU-AL AND AL-AL
BONDS USED IN MICROELECTRONICS
Proc. 7th Annual Reliability and
Maintainability Conf., pp. 532-536, } 11
San Francisco, Calif., July 1968.
(7), (21) 12
- (DEGRADATION) bond: TC, US; wire: Al, Au; film:
Al 4
Stress: thermal
Part: wire; bond
(Mechanism: anneal, intermetallics)
Test: pull; resistance
FABRICATION-bond: TC; wire: Au; film: Al
Bonding Surface: film thickness
EXPERIMENTAL

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4. Key Word Index Introduction

The three levels of key words indicating subject area are listed in alphabetical order in Section 4A with page numbers where they are located in section 4B. In section 4B these key words and descriptors are listed by the three subject areas: test, fabrication, and degradation. By each key word and descriptor is a tabulation of identification codes of entries to which this key word or descriptor was assigned in the bibliography. Key words and descriptors that may require additional definition are followed by explanatory phrases, in brackets. An excep-

tion is made for the test method key words. They are listed in alphabetical order in Table 4 with brief descriptions for each method.

To help identify key words of different level: first-level key words are in upper-case, second-level key words have only the first letter capitalized, and third-level key words are in lower-case. Descriptors are also in lower-case and are listed immediately below the associated first-level key words in section 4B.

4a Alphabetical Key Word Listing

KEY WORD - [DESCRIPTIVE PHRASE]

PAGE NUMBER IN SUBJECT AREA LISTING OF KEY WORDS (Section 4B)

adjustment - [of apparatus]	16
- [of bonding tool]	17
air blast - [description]	12
[evaluation]	13
anneal - [of wire, responsible for degradation or failure]	19
Apparatus: [bonding machines and accessories]	16
apparatus - [importance of rigidity]	17
- [evaluation of]	16
Application - [information applicable to test method]	12
bond - [affected by stress]	18
bond (adhesion) - [evaluation of]	16
bond monitor - [application]	13
- [correlation]	13
- [description of test method]	12
- [to evaluate fabrication procedures and processes]	17
bond temperature - [test method used to evaluate fabrication procedures and processes]	17
bond (type) - [evaluation of]	16
Bonding Surface - [information pertinent to the surface film(s) or metal substrate of bonding area]	17
care - [of wire]	17
centrifuge - [description of test method]	12
- [evaluation]	13
- [correlation]	13
- [to evaluate fabrication procedures and processes]	17
- [to determine degradation or failure]	20
- [to stress wire bond]	19
contamination - [of bonding surface as related to fabrication of wire bond]	17
- [of parts of the wire bond before or after bonding, responsible for degradation or failure]	19
- [of wire as related to fabrication of wire bond]	17
Control - [importance of control of bonding parameters]	17
Correlation - [between test methods]	13
corrosion - [responsible for degradation or failure of wire bond]	19
DEGRADATION - [degradation or failure]	18
description - [of apparatus]	16
Description - [of the test method]	12
design - [of apparatus]	17
- [of bonding tool]	17
device - [affected by stress]	19
electrical - [stress to wire bond]	19
electrical characteristics - [of wire]	17
electrical parameter - [test method to determine degradation or failure]	20
electron microprobe - [test method to determine degradation or failure]	20
electromigration - [responsible for degradation or failure]	20
evaluation - [of test methods]	13
Evaluation - [as related to fabrication of wire bonds]	16
FABRICATION - [of wire bonds]	13
fabrication - [of wire]	17
Failure Rates - [general reliability data; relative percentage of failure modes]	20
fatigue - [metal fatigue responsible for degradation or failure]	19
film thickness - [of bonding surface]	17
force - [control of in bonding]	17
grain growth - [responsible for degradation or failure]	20
hardening - [of wire and responsible for degradation or failure]	20
interferometer - [test method to evaluate fabrication procedures and processes]	17
intermetallics - [intermetallic compound formation or the Kirkendall effect responsible for degradation or failure]	20
IR monitor - [description of test method]	12
- [evaluation]	13
mechanical - [stress to wire bond]	19
mechanical shock - [description of test method]	12
- [evaluation]	13
- [application]	13
- [to evaluate fabrication procedures and processes]	17
- [to stress wire bond]	19

4A Alphabetical Key Word Listing (continued)

KEY WORD - [DESCRIPTIVE PHRASE]	PAGE NUMBER IN SUBJECT AREA LISTING OF KEY WORDS (Section 4B)
mechanical shock (radiation induced) - [description of test method]	12
- [evaluation]	13
- [correlation]	13
- [application]	13
- [to stress wire bond]	19
Mechanism - [of failure or degradation]	19
mechanical characteristics - [of bonding surface]	17
- [of wire]	17
metal system - [evaluation of, for fabricating wire bonds]	16
- [of bonding surface]	17
metallization - [affected by stress]	19
- [evaluation of, for fabricating wire bonds]	16
metallurgical exam - [description of test method]	12
- [to evaluate fabrication procedures and processes]	17
- [to determine degradation or failure]	20
metal system - [of bonding surface]	15
MIL-STD-883 - [description of test methods]	12
- [evaluation]	13
- [application]	13
MIL-STD-750B - [description of test methods]	12
moisture - [stress to wire bond]	19
noise - [description of test method]	12
- [evaluation]	13
orientation - [of bonding surface]	17
- [with respect to bonding tool]	17
oscillation - [of bonding tool]	17
package - [evaluation of]	16
- [importance of rigidity]	17
Part - [primarily or the wire bond, affected by stress]	19
photoelastic stress analysis - [test method used to evaluate fabrication procedures and processes]	17
power - [control of, in bonding]	17
Precautions - [in the use of a test method]	13
preparation - [of bonding surface for bonding]	17
Procedure - [for making a wire bond]	16
process - [stress on wire bond]	19
pull - [description of test method]	12
- [evaluation]	13
- [correlation]	13
- [application]	13
- [to evaluate fabrication procedures and processes]	18
- [to determine degradation or failure]	20
- [to stress wire bond]	19
pull (nondestructive) - [description of test method]	12
- [evaluation]	13
- [correlation]	13
- [to evaluate fabrication procedures and processes]	18
radiation - [stress to wire bond]	19
radiotracer - [test method used to evaluate fabrication procedures and processes]	18
resistance - [description of test method]	12
- [evaluation]	13
- [correlation]	13
- [precautions]	13
- [to evaluate fabrication procedures and processes]	18
- [to determine degradation or failure]	20
Rigidity - [importance of rigidity when fabricating wire bonds]	17
Schedule - [optimization of procedures and processes for making wire bonds]	16
Screening Procedures - [where a series of test methods are used]	13
shear - [description of test method]	12
- [evaluation]	13
- [to evaluate fabrication procedures and processes]	18
- [to determine degradation or failure]	20
size - [of wire]	17
spallation - [responsible for degradation or failure]	20

4A Alphabetical Key Word Listing (continued)

KEY WORD - [DESCRIPTIVE PHRASE]

PAGE NUMBER IN SUBJECT AREA LISTING OF KEY WORDS (Section 4B)

Stress - [stresses that produce weakened wire bonds as a result of the fabrication process or that result in degradation or failure of already completed wire bonds]	19
substrate - [affected by stress]	19
TC - [effects of process and material variable on making thermocompression wire bonds]	16
- [evaluation of thermocompression bonding]	16
- [failure rates of thermocompression wire bonds]	20
- [procedure for making thermocompression wire bonds]	16
- [schedule for optimizing procedures and processes for making thermocompression wire bonds]	16
- [theory of thermocompression bonding]	17
temperature - [importance of the control of]	17
temperature control - [evaluation of methods used in making thermocompression bonds]	16
temperature cycle - [description of the test method]	12
- [evaluation]	13
- [application]	13
- [to evaluate fabrication procedures and processes]	18
- [to determine degradation or failure]	20
- [to stress wire bond]	19
terminal - [importance of rigidity]	17
TEST - [test, evaluation, and screening methods for wire bonds]	12
Test - [used to evaluate fabrication procedures and processes]	17
Theory - [of thermocompression and ultrasonic bonding]	15
thermal mismatch - [responsible for degradation or failure]	20
thermal shock - [description of test method]	12
- [evaluation]	13
- [application]	13
- [to evaluate fabrication procedures and processes]	18
- [to stress wire bond]	19
thermal - [stress on wire bond]	19
time - [control of, in bonding]	17
Tool - [bonding tool, as related to the fabrication of wire bonds]	17
tool - [evaluation of]	16
topography - [of bonding surface]	17
- [of wire]	17
Trouble Shooting - [methods for locating and correcting deficiencies in wire bond fabricating procedures]	18
US - [effects of process and material variables on making ultrasonic wire bonds]	16
- [evaluation of ultrasonic bonding]	16
- [failure rates of ultrasonic wire bonds]	20
- [procedure for making ultrasonic wire bonds]	16
- [schedule for optimizing procedures and processes for making ultrasonic wire bonds]	16
- [theory of ultrasonic bonding]	17
US probe - [description of test method]	12
- [to evaluate fabrication procedures and processes]	18
US stress - [description of test method]	12
- [to stress wire bond]	19
Variables - [effects of process and material variables on the quality of wire bonds]	16
vibration (variable frequency) - [description of test method]	12
- [evaluation]	13
- [application]	13
- [to evaluate fabrication procedures and processes]	18
- [to determine degradation or failure]	20
vibration (monitored) - [description of test method]	12
- [evaluation]	13
vibration (fatigue) - [description of test method]	12
- [application]	13
- [to determine degradation or failure]	20
visual inspection - [description of test method]	13
- [evaluation]	13

4A Alphabetical Key Word Listing (continued)

<u>KEY WORD - [DESCRIPTIVE PHRASE]</u>	<u>PAGE NUMBER IN SUBJECT AREA LISTING OF KEY WORDS (Section 4B)</u>
- [correlation]	13
- [application]	13
- [to evaluate fabrication procedures and processes].	18
- [to determine degradation or failure]	20
visual inspection (SEM) - [description of test method].	13
- [to evaluate fabrication procedures and processes].	18
- [to determine degradation or failure]	20
wear - [of bonding tool].	17
wire - [affected by stress]	19
wire - [evaluation of, for different wire bonds].	16
Wire - [information pertinent to fabrication of wire bonds]	17
wire bond - [evaluation of]	16
x-ray - [description of test method].	13
- [evaluation].	13
- [to determine degradation of failure]	20

4B Subject Area Key Word Listing

TEST

TEST [test, evaluation, and screening methods for wire bonds]

bond

TC [thermocompression]

64D1, 64H2, 65B1, 65C2, 67A1, 67G1, 67H1, 67S4, 68D2, 68F1, 68P1, 68R1, 69A1, 69K4, 69S1, 70A1, 70B1, 70H2, 71B3, 71H2, 71S1

US [ultrasonic]

59J1, 60J1, 61J1, 62J1, 64C2, 64W1, 66R1, 67P2, 67R1, 67R2, 68D2, 68F1, 68R1, 69B6, 69B7, 69K1, 69K4, 69P1, 70A1, 70B2, 70D2, 71B1, 71B4, 71G1

wire

Al [aluminum hardened with silicon]

64D1, 66R1, 67R1, 67R2, 68D2, 68R1, 69B5, 69B6, 69B7, 69K1, 69K4, 69P1, 70A1, 70B2, 70D2, 71B1, 71B4, 71G1

Al (pure) [pure aluminum]

67R2

Au [gold]

65C2, 67A1, 67G1, 67H1, 68D2, 68L1, 68P1, 69A1, 69B5, 69K4, 69S1, 70A1, 70B1, 70H2, 71B3, 71H2, 71S1

Au/Cu [gold plated copper]

67S4

film [metal or metal film(s) of bonding surface]

Ag [silver]

70B1, 71B3

Al [aluminum]

65C2, 67A1, 67R1, 67R2, 68D2, 68P1, 69B6, 69B7, 69K1, 69K4, 69P1, 70A1, 70B2, 70D2, 71B1, 71B4, 71G1, 71S1

Au [gold]

67A1, 67H1, 67S4, 68D2, 69P1, 69K4, 70A1, 70B1, 70D2, 71B3, 71S1

Au/Cr [gold on chromium]

66R1, 67R1, 67R2

Au/Mo [gold on molybdenum]

67G1

substrate [material underlying bonding surface film(s)]

alumina

66R1, 67R1, 67R2

beryllia

66R1, 67R1

ceramic

67S4

sapphire

66R1, 67R1, 67R2

Si [silicon]

67R1, 67R2

silica (96%)

67R1, 67R2

application

plastic devices

70B1, 70C2, 70H2, 71B3, 71H2

hybrid devices

70S2, 71S1

Description [of the test method]

air blast

68D2

bond monitor

59J1, 60J1, 61J1, 62J1, 64W1, 67P2, 69B6, 69B7, 71B4

centrifuge

63W1, 66L4, 66P1, 68B1, 68D2, 68I1, 69B2, 69O1, 69S4, 70B7, 70D3

IR monitor

67B1, 67S4, 68B1

mechanical shock

63W1, 66P1, 67I1, 68D2, 69B2, 69S4, 70D3, 71N2, 71K1

mechanical shock (radiation-induced)

58F1

metallurgical exam

68B1

MIL-STD-883

68D2, 69O1, 70C2, 71N1

MIL-STD-750B

66P1

noise

65M1

pull

63W1, 65W1, 67H1, 68B1, 68D2, 68P1, 69K1, 69O1, 69S1, 70A1, 70B7, 71N1, 71N2

pull (nondestructive)

65B1, 69S1

resistance

66M1, 68D2, 70B2, 70H2, 71H2, 71N1, 71N2

shear

67A1, 68D2

temperature cycle

66L4, 66P1, 68D2, 69O1, 69S4, 70H2, 71H2

thermal shock

63W1, 68D2, 69B2, 69S4, 70D3

US probe

59R1, 67B4

US stress

69K4, 70B7

vibration (fatigue)

66I1, 68D2, 69S4, 70D3

vibration (monitored)

66L4, 68D2, 70D3

vibration (variable frequency)

63W1, 66I1, 66P1, 68D2, 69S4, 70D3

4B Subject Area Key Word Listing (continued)

TEST - FABRICATION

visual inspection 66P1, 66L4, 68D2, 68R1, 6901, 71N1	pull (nondestructive) 69A1
visual inspection (SEM) 69S1, 71N1	resistance 66R1, 67R1, 67R2
x-ray 66L4, 68D2, 68L1, 69S1	visual inspection 67B7, 67G1, <u>69K1</u> , 69P1, 70D2, 71G1
Evaluation [of the test method]	Application [information relevant to a particular test method]
air blast 69P1	bond monitor 64C2, <u>70B7</u> , 71K2
centrifuge 66L4, 67G1, 68H4, 6901	mechanical shock <u>61A2</u> , <u>69K2</u>
IR monitor 67S4	mechanical shock (radiation-induced) 67G2, 70M2
mechanical shock 68F1, 68H4	MIL-STD-883 6938, 69D3, 71N1
mechanical shock (radiation-induced) 68F1	pull 67S3, 68A1, 69B5, 69D1, 70A6, 70B8, 71B4
MIL-STD 883 <u>70S2</u>	temperature cycle <u>69K2</u> , <u>70P2</u> , 70V1
noise 68B1	thermal shock <u>69K2</u> , <u>70P2</u>
pull 67R2, 68H4, <u>70B8</u> , 71B1	US probe 69D2
pull (nondestructive) 64D1	vibration (fatigue) <u>69K2</u>
resistance 67R2, 68B1, 70H2, 71H2	visual inspection 68H1
shear 67G1	Precautions [in the use of a test method] resistance 65C2, 68E1
temperature cycle 66L4, 68H4, 69B1, 70H2, 71H2	Screening Procedures [where a series of tests is used to cull out unsatisfactory wire bonds] 66P1, 67G1, 67P1, <u>68D2</u> , 69D3, 69L1, <u>70S2</u> , 71N1, 71S1
thermal shock 65H3, 68H4, 69B1, 69P1, 70B1, 71B3	
vibration (monitored) 66L4	
vibration (variable frequency) 69S4	
visual inspection 64H2, 66L4, 67G1, 68H4, <u>69K1</u> , 6901, 69P1, 69S4	
x-ray 66L4, 67G1, 68H4	
Correlation [between methods for the same type of wire bond]	
bond monitor 69B7	
centrifuge 65B1	
mechanical shock-(radiation-induced) 69P1, 70D2	
pull 65B1, 66R1, 67R1, 67R2, 69A1, 69B7, <u>69K1</u> , 69P1, 70D2, 71G1	
	FABRICATION
	bond
	TC [thermocompression]
	57A1, 57A2, 58C1, 61A1, 62M1, 63M1, 63P1, 63W1, 64A1, 64D1, 64H1, 64H2, 64J1, 64M1, 65B1, 65C1, 65C5, 65H1, 65H2, 65R1, 65S1, 65S3, 66A1, 66A2, 66B1, 66B3, 66B4, 66B6, 66C1, 66E1, 66G2, 66H1, 66K3, 66L1, 67A2, 67B2, 67C1, 67H1, 67K1, 67P1, 67R4, 67S1, 67S5, 68A2, 68A3, 68B1, 68D1, 68G1, 68H3, 68H5, 68J1, 68K1, 68M1, 68M2, 68M3, 68P1, 68R2, 68T2, 69A2, 69B3, 69G2, 69O2, 69S1, 69S2, 69S5, 69T2, 70A2, 70D4, 71B2, 71M1, 71P1, 71R1
	US [ultrasonic]
	59A1, 59J1, 59V1, 60J1, 60J2, 60W1, 61D1, 61J1, 62F1, 63W1, 64D2, 65D1, 65J1, 65N1, 66B1, 66B6, 66E1, 66H1, 66L3, 66R1, 67B2, 67H2, 67J1, 67L1, 67P1, 67R1, 67R2, 67S1, 67T1, 68B1, 68D1, 68H3, 68K1, 68M1, 68M2,

4B Subject Area Key Word Listing (continued)

FABRICATION

68S1, 68T2, 68U1, 68U2, 68U3, 68U4, 68U5,
69B2, 69B3, 69E5, 69B6, 69K1, 69K3, 69L2,
69O2, 69P1, 69S1, 69S2, 69S5, 69T2, 69U1,
69U2, 70B2, 70B3, 70B5, 70B6, 70B7, 70B8,
70C1, 70D2, 70D4, 70P1, 70W1, 71B1, 71B2,
71B4, 71D1, 71G1, 71H1, 71J1, 71M1, 71P1,
71P2, 71R1

wire

Ag [silver]
57A1, 57A2, 58C1, 61A1, 62M1, 63W1, 64A1,
66A1, 66C1, 66G2

Al [aluminum hardened with silicon]
57A1, 57A2, 58C1, 61A1, 63M1, 63W1, 64A1,
64D1, 64S1, 65B1, 65D1, 65T1, 66A1, 66B4,
66G2, 66R1, 67B2, 67C1, 67K1, 67L1, 67P1,
67R1, 67R2, 67S1, 67S5, 67V1, 68G1, 68H3,
68K1, 68M2, 68R2, 68T2, 68U1, 69B2, 69B3,
69B5, 69B6, 69K1, 69K3, 69O2, 69P1, 69S1,
69S2, 69U1, 70B2, 70B3, 70C1, 70D2, 70D4,
70P1, 71B1, 71B2, 71G1, 71J1, 71P1, 71P2,
71R1

Al/Mg [aluminum hardened with magnesium]
67V1, 68U1, 69U1, 70P1

Al (pure) [pure aluminum]
67R2, 67V1, 69O2

Au [gold]
57A1, 57A2, 58C1, 61A1, 62M1, 63M1, 63P1,
63W1, 64A1, 64C1, 64H1, 64H2, 64M1, 64S1,
65B1, 65C5, 65D1, 65H1, 65H2, 65R1, 65S1,
66A1, 66B3, 66B4, 66C1, 66G2, 66L1, 66W1,
67B2, 67C1, 67H1, 67K1, 67P1, 67S1, 67S5,
67T1, 68A3, 68H3, 68K1, 68M2, 68M3, 68P1,
68R2, 68S1, 68T2, 68U1, 69A2, 69B3, 69G2,
69P1, 69S1, 69S2, 69S3, 69U1, 70A2, 70A3,
70D4, 71B2, 71P1

Au/Ag [gold with silver added]
66W1

Au/Cu [gold plated copper]
61A1, 66C1

Au/CuBeO [gold plated CuBeO]
71D1

Au/Ga [gold with gallium added]
68S1

Au/Ni [gold covered nickel]
64C1

Au/Pt [gold covered platinum]
64C1

Au/W [gold covered tungsten]
64C1

Cu [copper]
57A1, 57A2, 61A1, 62M1, 63M1

Cu/Ni [gold plated nickel]
66C1

Pb [lead]
57A2

P1 [palladium]
63W1

Pt [platinum]
57A2, 63M1, 65C1

Sn [tin]
57A2

Sn/Cu [tinned copper]
61A1

Ti [titanium]
63M1

Zr [zirconium]
63M1

film

Ag [silver]
63W1, 66G2, 67P1

Ag/Al [silver on aluminum]
63W1, 68T2

Ag/Cr [silver on chromium]
63W1, 64S1, 66G2, 67K1, 67P1, 67S5, 68K1

Ag/Cr-Al [silver on chromium-aluminum al-
loy]
63W1

Al [aluminum]
62M1, 63M1, 63W1, 64D1, 64H1, 64H2, 64M1,
64S1, 65B1, 65C5, 65H1, 65H2, 65R1, 65R2,
65S1, 66A1, 66B3, 66B4, 66G2, 66H1, 66W1,
67B2, 67C1, 67H1, 67K1, 67L1, 67P1, 67R1,
67R2, 67S1, 67S5, 68A3, 68G1, 68H3, 68K1,
68M2, 68M3, 68P1, 68R2, 68T2, 69A2, 69B2,
69B5, 69B6, 69K1, 69O2, 69P1, 69S1, 69S2,
69U1, 70A2, 70B2, 70B3, 70C1, 70D2, 70D4,
71B1, 71G1, 71J1, 71P1, 71P2

Al/Cr [aluminum on chromium]
63P1, 66H1, 67E2, 67R2

Au [gold]
63W1, 64D1, 64S1, 64B1, 65C5, 65R1, 66A1,
66B4, 66G2, 66H1, 67B2, 67H1, 67K1, 67P1,
67S1, 68H3, 68K1, 68R2, 69A3, 69B2, 69B3,
69K3, 69O2, 69P1, 69S1, 69U1, 70D2, 70D4,
71G1, 71J1, 71P1

Au/Ag [gold on silver]
65C5

Au/Ag/Cr [gold on silver on chromium]
69S3

Au/Ag/Cr-Al [gold on silver on chromium-
aluminum alloy]
63W1

Au/Al [gold on aluminum]
63M1

AuAl2 [gold-aluminum compound]
68T2

Au/Co [gold on cobalt]
65C5

Au/Cr [gold on chromium]
63P1, 63M1, 65C5, 66H1, 66R1, 67B2, 67L1,
67R1, 68M2, 69S2

4B Subject Area Key Word Listing (continued)

FABRICATION

Au/Cu [gold plated copper] 71D1	Ti [titanium] 63M1
Au/Cu/Ti [gold on copper on titanium] 68M2	thick film
Au/Cr/Al [gold on chromium on aluminum] 68K1	Ag [silver] 69B3
Au/Mo [gold on molybdenum] 65C6, 66G2, 67C1, 67P1, 67S1, 67S5, 68M2, 69S2, 69S3	Ag/Pd [silver-palladium composition] 69B3
Au/Mo/Al [gold on molybdenum on aluminum] 67S5, 70A2	Au [gold] 69B3
Au/Mo/Mn [gold on molybdenum on manganese] 69B3	Au/Pd [gold-palladium composition] 69B3
Au/Mo/Pt [gold on molybdenum on platinum] 67C1, 67K1, 68K1	Au/Pd/Pt [gold-palladium-platinum composition] 69B3
Au/Ni [gold on nickel] 65C5, 68M2	Au/Pt [gold-platinum composition] 69B3
Au/NiCr [gold on nichrome] 65S1	Pd/Ag [palladium-silver composition] 69B3
Au/P1 [gold in palladium] 63W1	substrate
Au/Pt/Ti [gold on platinum on titanium] 67S5, 68M2	Al [aluminum] 66B4
Au/Pt/Ti/Pt [gold on platinum on titanium on platinum] 69S3	alumina 65R2, 65S1, 66C1, 66R1, 67L1, 67R1, 67R2, 68H3
Au/Ti/Al [gold on titanium on aluminum] 69S3, 70A2	beryllia 66R1, 67L1, 67R1
Bi [bismuth] 62M1	BN [boron nitride] 65R2
Cr [chromium] 68H3, 68T2	ceramic 63P1, 66H1
Cr/Al [chromium on aluminum] 64S1, 67S5, 69S3	epoxy 71D1
Cu/NiCr [copper or nichrome] 65S1	Fe/Ni/Co [iron-nickel-cobalt alloy] 65B1, 66B4, 69K3, 71G1, 71J1
Ga [gallium] 62M1	Ge [germanium] 57A1, 57A2, 57C1, 61A1, 62M1, 65D1
In [indium] 62M1	glass 63P1, 65D1, 65H1, 65H2, 65R2, 66C1, 66H1, 67L1, 68H3
Ni [nickel] 66A1	sapphire 66R1, 67L1, 67R2
NiCr [nichrome] 63M1	Si [silicon] 57A1, 57A2, 57C1, 61A1, 62M1, 63M1, 64A1, 64H2, 65C1, 65C5, 65D1, 65R2, 65S1, 66A1, 66B4, 67L1, 67P1, 67R2, 68H3, 68T2
P1 [palladium] 64S1	silica (96%) 67L1, 67R1, 67R2
Pt [platinum] 64H2, 64S1	application
Pt/Ti [platinum on titanium] 68M2	hybrid devices 67L1, 67R1, 68H3, 68M3, 69T2
Sb [antimony] 62M1	Theory [of bonding]
Ta [tantalum] 63M1	TC [thermocompensation] 57A2, 61A1, 63M1, 64A1, 66A1, 66B4, 66B6, 67B2, 68B1, 69S1

4B Subject Area Key Word Listing (continued)

FABRICATION

US [ultrasonic]
59A1, 59J1, 59W1, 60J1, 60J2, 60W1, 61J1,
62P1, 65D1, 65J1, 65N1, 65P1, 66B6, 67B2,
67J1, 68B1, 68U2, 68U3, 68U4, 69P1, 69S1,
69U1, 70B3, 70B8, 71P2

Evaluation [of]
 TC [thermoccompression bonding]
63P1, 63W1, 66B1, 66C1, 66E1, 67B2, 67S1,
68H3, 68K1, 68M1, 69C1, 69S1, 69T2, 70D4,
71B2

US [ultrasonic bonding]
60J2, 61J1, 62P1, 63W1, 66B1, 66E1, 66R1,
67B2, 67L1, 67R1, 67S1, 68H3, 68K1, 68M1,
69C1, 69S1, 69T2, 70D4, 71B2, 71P2

wire bond [wire bonds, in general, and versus
 other bonding methods]
67L1, 69B2, 69B3, 69C1, 69S5, 70D4, 70M1,
71B2, 71M1

apparatus (US) [ultrasonic bonding equipment]
61D1

bond (adhesion)
57A2, 63M1, 63P1

bond (ball)
64M1, 65B1, 65R1, 66B4, 66E1, 66G2, 66L1,
67B2, 67C1, 67K1, 68M3, 68R2, 69B6, 69C1

bond (stitch)
65D1, 65R1, 66E1, 66L1, 67B2, 68M3, 68R2,
69C1

bond (wedge)
65B1, 65R1, 66B4, 66E1, 66G2, 66L1, 67B2,
67C1, 67K1, 68R2, 69C1

bond (general)
66C2

metal system [of the wire bond, i.e. wire-
 metallization-substrate, for]
 (TC) [thermoccompression bonds]
63W1, 64S1, 65C5, 65R2, 66G2, 67K1, 67P1,
67S5, 68M2, 68T2, 70A2
 (US) [ultrasonic bonds]
61J1, 67P1, 67R2, 68M2, 68T2
 (general) [bond type not specified]
66W1, 69S3

metallization
65C5, 66H1, 67C1, 67P1, 68T2, 69B3, 69S2

package
67G1

temperature control [for thermocompression
 bonding]
66L1, 67K1, 68H3, 71B2

tool
 (TC) [to make thermocompression bonds]
63W1, 64M1, 65B1, 66B4, 68H3
 (US) [to make ultrasonic bonds]
63W1

wire
 (TC) [for thermocompression wire bonds]
65B1, 65R1, 65R2, 66G2, 67P1, 68H3, 68R2,
71R1
 (US) [for ultrasonic wire bonds]
63W1, 67P1, 68U1, 69U1, 70C1, 70P1, 71R1
 (ribbon)
65B5, 69B6
 (general)
66W1

Procedure [for making a wire bond]
 TC [thermoccompression]
57A1, 57C1, 60J2, 61A1, 62M1, 64H2, 64M1,
65C1, 65R1, 65S1, 66A2, 66L1, 67A2, 67B2,
67H1, 67K1, 67P1, 68A2, 68B1, 68H5, 68K1,
68R2, 69G2, 69S1, 71B2
 US [ultrasonic]
60J1, 65J1, 65N1, 67B2, 67P1, 67R2, 67T1,
68B1, 68K1, 69K2, 69K3, 69S1

Schedule [optimization of procedures and process-
 es for making wire bonds]
 TC [thermoccompression]
57A1, 63M1, 63P1, 64A1, 64H2, 65B1, 66A1,
66C1, 67B2, 67H1, 68B1, 68K1
 US [ultrasonic]
59A1, 59W1, 60J1, 60W1, 61J1, 63W1, 65J1,
66R1, 67J1, 67L1, 67R1, 67R2, 68K1, 68U1,
68J4, 69P1, 69U1, 70B8, 70D2

Variables [effects of process and material var-
 iables on quality of wire bond]
 TC [thermoccompression bond]
57A1, 57C1, 59A1, 61A1, 63M1, 63P1, 64A1,
64H2, 65H1, 65H2, 66A1, 66B1, 66C1, 66L1,
67B2, 67H1, 67K1, 68P1, 69B3
 US [ultrasonic bond]
59W1, 60J1, 60J2, 60W1, 61J1, 63W1, 65D1,
65J1, 65N1, 66B1, 67J1, 67R1, 69B3, 69P1,
70D2, 71J1

Apparatus [of bonding machines and accessories]
 adjustment (TC) [of thermocompression bond-
 ing apparatus]
67H1, 63W1
 adjustment (US) [of ultrasonic bonding ap-
 paratus]
64D2, 68U5, 69B6, 69P1, 69U1, 70B3, 70D2,
71B4, 71H1
 description (TC) [of thermocompression bond-
 ing apparatus]
68D1, 68H3
 description (US) [of ultrasonic bonding ap-
 paratus]
60J1, 62P1, 63W1, 67B2, 67L1, 67R2, 68D1,
69U1

4B Subject Area Key Word Listing (continued)

FABRICATION

design (TC) [of thermocompression bonding apparatus]
63M1, 63W1, 64J1, 64M1, 65S3, 66A2, 66K3, 67A2, 67R4, 68H5

design (US) [of ultrasonic bonding apparatus]
59A1, 59W1, 60J2, 60W1, 63W1, 65D1, 65J1, 65N1, 67H2, 67J1, 67S1, 68B1, 68U5, 69L2, 69U1, 69U2, 70B2, 70B3, 70B6, 70D2, 70W1, 71B4, 71J1

Control [importance of control of]
force (TC) [applied in making thermocompression bond]
68P1

force (US) [applied in making ultrasonic bond]
68U4, 70C1

power (US) [used in making ultrasonic bond]
68U4, 70C1

temperature (TC) [in making thermocompression bond]
64H2, 65H1, 65H2, 65S1, 66C1, 66L1, 68B1, 68E3, 68J1, 68M3, 68P1

temperature (US) [in making ultrasonic bond]
68B1

time (US) [for making ultrasonic bond]
68U4, 70C1

Tool [bonding]
adjustment (US) [for ultrasonic bonding]
69U1, 70B2, 70B3, 71H1, 70D2

design (TC) [for thermocompression bonding]
63W1, 64H2, 65B1, 65S3, 66B4, 66C1, 67B2, 67R3, 67S1, 68B1, 68H3, 69G1, 71B2

design (US) [for ultrasonic bonding]
59W1, 60W1, 63W1, 65D1, 67R1, 67R3, 67S1, 67T1, 68U1, 69G1, 69P1, 70B2, 70B7, 70D2, 71B1, 71D1, 71G1, 71J1

oscillation (US) [of the ultrasonic bonding tool]
69B6, 70B2, 70B3, 70D2, 70W1, 71B1, 71D1, 71H1

wear (TC) [of the thermocompression bonding tool]
68H3

wear (US) [of the ultrasonic bonding tool]
67R1, 71J1

Rigidity [importance of in]
apparatus
67R2, 68U5, 69P1, 69U1, 70B2, 70B3, 70B7, 70B8, 70D2, 71B1, 71B4, 71J1

terminal [device]
68U5, 69P1, 70D2, 71B2

package
69U1, 70D2, 71J1

Wire
care
64C1, 67B2, 68S1, 70A3

contamination
65K1, 70A3, 70B3

electrical characteristics
66R1, 67R1, 69O2, 70A7

fabrication
69O2, 70C1

mechanical characteristics
63W1, 65C1, 65K1, 66L3, 67R2, 67V1, 68G1, 68S1, 68U1, 69D2, 69O2, 69U1, 70A3, 70A4, 70B3, 70B5, 71B4, 71R1

size
66C1, 66K2, 68B2, 70A3, 70A4, 70A5

topography [of the surface]
65K1, 69O2

Bonding Surface [of film(s) or metal substrate]
contamination
59W1, 60W1, 64H2, 65B1, 66B4, 66C1, 69A3, 69H1, 69P1, 70D2, 71G1

film thickness
64H1, 65C5, 65H1, 65H2, 66B3, 66G2, 66R1, 67L1, 67R1, 67R2, 68A3, 69A2, 69A3, 69K1, 69K3, 70D2, 71G1, 71P1

mechanical characteristics
59W1, 60W1, 69A3, 69P1, 71H3

metal system
67C1, 68T2, 71G1

orientation [with respect to the bonding tool]
68S1

preparation
59W1, 60W1, 63P1, 64H1, 65H1, 65H2, 65R2, 66H1, 67C1, 67L1, 67R2, 68T2, 69A3, 69B3, 70A2, 70B3, 71G1

topography
59W1, 60W1, 63P1, 64H2, 65D1, 66R1, 67L, 67R1, 67R2, 69A3, 69P1, 70D2, 70P1, 71J, 71P2

Test [used to evaluate fabrication procedures and processes]
bond monitor
59A1, 59W1, 61J1, 65J1, 65P1, 67J1

bond temperature
61J1

centrifuge
63W1, 64M1, 65B1, 65R1, 67K1, 68R2, 69B2

interferometer
70B2, 70W1

mechanical shock
63W1, 64M1, 65R1, 68R2, 69B2

metallurgical exam
59W1, 60J1, 60J2, 60W1, 61J1, 65H2, 65J1, 66C2, 67J1

photoelastic stress analysis
61J1

4B Subject Area Key Word Listing (continued)

FABRICATION - DEGRADATION

pull
57C1, 59W1, 60W1, 61A1, 63M1, 63P1, 63W1,
64H2, 65B1, 65C5, 65H1, 65H2, 65J1, 65S1,
66B4, 66C1, 66G2, 66R1, 66W1, 67H1, 67K1,
67L1, 67R2, 68B1, 68U1, 69B3, 69O2, 69P1,
69S1, 69U1, 70B3, 70B7, 70B8, 70C1, 70D2,
71J1, 71G1

pull (nondestructive)
65B1, 66B4

radiotracer
61J1, 69H1

resistance
63M1, 63P1, 66G2, 66R1, 67R2, 70C1

shear
61D1, 64A1, 66A1

temperature cycle
63P1, 69B2

thermal shock
63P1, 63R1, 64M1, 66C1, 67R2

US probe
69D2

vibration (variable frequency)
63W1, 64M1, 65R1, 68R2

visual inspection
57A1, 60J1, 61A1, 63M1, 63P1, 67L1, 67R2,
68U1, 69P1, 69U1, 70C1, 70D2, 71G1

visual inspection (SEM)
69C2, 70B7, 70B8

Trouble Shooting [methods for locating and cor-
recting deficiencies in fabri-
cating procedures]
69U1, 71H1

DEGRADATION [degradation or failure]

bond
TC [thermocompression]
61G1, 64P1, 64S1, 64U1, 65C3, 65C4, 65C5,
65H1, 65H2, 65R1, 65R2, 65S2, 66B2, 66B3,
66B4, 66B5, 66G2, 66L2, 67A1, 67A3, 67B3,
67C1, 67G1, 67K1, 67K2, 67P1, 67S1, 67S5,
68A3, 68F1, 68G1, 68G2, 68H2, 68M1, 68M2,
68P1, 68R2, 69A2, 69B3, 69B4, 69C4, 69L1,
69O1, 69O2, 69S1, 69T1, 70A1, 70A2, 70B1,
70D1, 70H2, 70R1, 70S2, 70V1, 71B3, 71H2,
71P1, 71R1, 71S1

US [ultrasonic]
59W1, 60W1, 66K1, 66L3, 66R1, 67A3, 67C3,
67F1, 67L1, 67R1, 67R2, 67S1, 68A3, 68F1,
68M1, 68U1, 69B5, 69K3, 69K4, 69L1, 69O1,
69O2, 69P1, 69U1, 70A1, 70B2, 70B8, 70C1,
70P1, 70V1, 71B1, 71B4, 71G1, 71G2, 71P1,
71R1

wire
Al [aluminum hardened with silicon or so
implied]
64S1, 64U1, 65C5, 65R1, 66B4, 66K1, 66R1,
67A3, 67C1, 67L1, 67P1, 67R1, 67R2, 67S1,
67S2, 67S5, 68F1, 68G1, 68G2, 68M1, 68R2,
68U1, 69B4, 69B5, 69K3, 69K4, 69L1, 69O1,
69O2, 69P1, 69S3, 69U1, 70A1, 70B1, 70B3,
70P2, 70V1, 71B1, 71B4, 71G2, 71P1, 71R1

Al (pure) [pure aluminum]
67R2, 70P2

Al/Mg [aluminum hardened with magnesium]
69P1, 70P1

Au [gold]
61G1, 64P1, 64S1, 64U1, 65C3, 65C4, 65C5,
65H1, 65H2, 65R1, 65R2, 65S2, 66B2, 66B3,
66B4, 66B5, 66G2, 66L2, 67A1, 67B3, 67C1,
67C3, 67G1, 67K1, 67K2, 67P1, 67S1, 67S5,
67A3, 68F1, 68G1, 68H2, 68L1, 68M1, 68M2,
68P1, 68R2, 69A2, 69B3, 69B4, 69K4, 69L1,
69O1, 69S1, 69S3, 69T1, 70A1, 70A2, 70B1,
70D1, 70H2, 70P2, 70R1, 70V1, 71B3, 71G1,
71H2, 71P1, 71S1

film
Ag [silver]
69T1

Ag/Cr [silver or chromium]
67S5

Al [aluminum]
64P1, 64S1, 64U1, 65C3, 65C4, 65C5, 65H1,
65H2, 65R1, 65R2, 65S2, 66B2, 66B3, 66B5,
66B7, 66G2, 66K1, 67A1, 67B3, 67C1, 67C3,
67K1, 67K2, 67L1, 67F1, 67R1, 67R2, 67S1,
67S5, 67A3, 68G1, 68G2, 68H2, 68M2, 68P1,
68R2, 68U1, 69A2, 69B4, 69B5, 69K4, 69L1,
69O1, 69O2, 69S1, 69S3, 69T1, 70A1, 70A2,
70B2, 70C1, 70D1, 70R1, 70V1, 71B1, 71B4,
71P1, 71S1

Au [gold]
64S1, 64U1, 65C5, 65R1, 65S2, 67A1, 67P1,
67S1, 68H2, 68M2, 68R2, 69K3, 69K4, 69L1,
69O1, 69O2, 69S3, 69T1, 70A1, 70B1, 71B3,
71P1, 71S1

Au/Cr [gold on chromium]
66R1, 67L1, 67R1, 67R2

Au/Mo [gold on molybdenum]
65C5, 67C1, 67G1, 67P1, 67S1, 67S5, 69B4

Au/Mo/Al [gold on molybdenum on aluminum]
67S5, 70A2

Au/Mo/Pt [gold on molybdenum on platinum]
67C1

Au/Pt/Ti [gold on platinum on titanium]
67S5

Au/Ti/Al [gold on titanium on aluminum]
70A2

Cr/Al [chromium on aluminum]
67S5

Ni [nickel]
69T1

thick film
Ag/Pd [silver-palladium composition]
69R3

4B Subject Area Key Word Listing (continued)

DEGRADATION

Au [gold]
 69B3, 71G2

substrate
 alumina
 65R2, 66R1, 67L1, 67R2
 beryllia
 66R1, 67L1
 BN [boron nitride]
 65R2
 FeNiCo [iron-nickel-cobalt alloy]
 64S1, 66B4, 66K1, 67P1, 69K3
 glass
 65H1, 65H2, 65R2
 sapphire
 66R1, 67L1, 67R2
 Si [silicon]
 61G1, 64S1, 65R2, 65S2, 67L1, 67P1, 67R2, 69U1
 silica (95%)
 67R2, 67L1
 application
 plastic device
 68L1, 69T1, 70B1, 70B4, 70H1, 70H2, 71B3, 71H2
 hybrid devices
 67L1, 70S2, 71L1, 71S1

Stress [that produces a weakened wire bond as a result of the fabrication process or that results in degradation or failure of an already completed wire bond]
 electrical
 67B3
 mechanical
 70W2
 moisture
 66B7, 69T1, 70B4, 70H2, 71H2, 71L1
 process
 59W1, 60W1, 61G1, 64P1, 64U1, 65R2, 65S2, 66B2, 66B5, 66G1, 66K1, 66L3, 67A3, 67C2, 67G1, 67P1, 67L1, 67R1, 67R2, 67S1, 67S5, 68H2, 68L1, 68M2, 68P1, 68U1, 69L1, 69U1, 70B4, 70B8, 70C1, 71B1, 71B4, 71G1
 radiation
 66L2, 66O1
 test (centrifuge)
 64P1, 64U1, 65S2, 67G1, 67S1, 71S1
 test (mechanical shock)
 65U1, 71S1
 test (mechanical shock (radiation-induced))
 68F1
 test (mechanical shock)
 71S1
 test (pull)
 70A1, 70B8

test (temperature cycle)
 66K1, 70B4, 70H1, 70H2, 71H2, 71L1, 71P1, 71S1
 test (thermal shock)
 64U1, 67G1, 67R2, 69T1, 70B1, 70B4, 70H1, 71B3, 71S1
 test (US stress)
 69K4
 thermal
 61B1, 64S1, 64U1, 65C3, 65C4, 65C5, 65H1, 65H2, 66R1, 65R2, 65S2, 66B3, 66B4, 66B5, 66G2, 66K1, 66R1, 67A1, 67B3, 67C1, 67C3, 67G1, 67K2, 67L1, 67P1, 67R1, 67R2, 67S1, 67S2, 67S5, 67A3, 68G1, 68G2, 68P1, 68R2, 68T1, 69A2, 69B3, 69B4, 69B5, 69K3, 69L1, 69O1, 69O2, 69P1, 69S1, 69S3, 69T1, 70A1, 70A2, 70B2, 70C1, 70P1, 70P2, 70R1, 70V1, 71G2, 71P1, 71R1

Part [part affected, primarily of the wire bond]
 bond
 59W1, 60W1, 61B1, 64P1, 64S1, 64U1, 65C3, 65C4, 65C5, 65H1, 65H2, 65R1, 65R2, 65S2, 66B2, 66B3, 66B4, 66B5, 66G1, 66G2, 66K1, 66L2, 66O1, 67A1, 67A3, 67B3, 67C1, 67C2, 67C3, 67G1, 67K2, 67L1, 67P1, 67R1, 67R2, 67S1, 67S5, 68A3, 68F1, 68H2, 68M2, 68P1, 68T1, 69A2, 69B4, 69K3, 69K4, 69S1, 69S3, 69T1, 70A2, 70B1, 70B8, 70D1, 70R1, 70H2, 71R3, 71B4, 71G2, 71H2, 71P1, 71S1
 metallization
 64U1, 65S2, 66B7, 66R1, 67G1, 67L1, 67R1, 67R2, 68M2, 69A2, 70B4, 70H2, 71H2, 71L1
 substrate
 61G1, 65S2, 67G1, 68M2, 68U1, 69U1, 70C1
 wire
 64P1, 64U1, 65H1, 65H2, 65K1, 65S2, 66B2, 66B4, 66G1, 66G2, 66K1, 66L3, 67A3, 67G1, 67L1, 67R2, 67S1, 67S5, 67A3, 68G1, 68G2, 68H2, 68L1, 69B5, 69K1, 69O2, 69P1, 69T1, 70A1, 70B1, 70B2, 70B4, 70C1, 70H2, 70V1, 70W2, 71B1, 71B3, 71B4, 71G1, 71G2, 71H2, 71L1, 71P1, 71R1, 71S1
 device [the device of which the wire bond is a part]
 67S2, 69P1, 70P1

Mechanism
 anneal [wire anneal]
 66K1, 67S5, 68A3, 69P1, 69B5, 69L1, 69O1, 69O2, 69P1, 70A1, 70B2, 70C1, 71B4, 71R1
 contamination [on or in the parts of the wire bond before or after bonding]
 65S2, 66G1, 66K1, 67C2, 67G1, 67P1, 67S2, 68H2, 68M2, 69L1, 69P1, 70D1, 70P1, 71L1
 corrosion
 65S2, 66B7, 67C1, 69T1, 70B4, 70H2, 71H2, 71L1
 fatigue [metal fatigue]
 59W1, 60W1, 65K1, 68C1, 68G2, 70L4, 70V1, 70W2, 71L1, 71P1, 71R1

4B Subject Area Key Word Listing (continued)

DEGRADATION

electromigration 67B3	x-ray 68L1, 70B4
grain growth 66G2, 66K1, 68P1, 69O2, 70A1, 71R1	Failure Rates [general reliability data; relative percentages of failure modes]
hardening [of the wire] 59W1, 60W1, 66L3	TC [thermoccompression wire bonds] 64U1, 66B2, 67G1, 67P1, 67S1, 68H2, 68M1, 68R2, 69B4, 69K4, 69L1, 69Q1, 70S2, 70V1
intermetallics [intermetallic compounds and the Kirkendall effect] 61B1, 64P1, 64S1, 64U1, 65C3, 65C4, 65C5, 65H1, 65H2, 65R1, 65R2, 65S2, 66B2, 66B3, 66B4, 66B5, 66G1, 66G2, 66W1, 67A1, 67A3, 67B2, 67B3, 67C1, 67C3, 67C4, 67K1, 67K2, 67L1, 67P1, 67R1, 67R2, 67S1, 67S5, 68A3, 68H2, 68M2, 68P1, 68R2, 68T1, 69A2, 69B4, 69K3, 69L1, 69Q1, 69S1, 69S3, 70A2, 70P2, 70R1, 71L1, 71P1	US [ultrasonic wire bonds] 67P1, 67S1, 68M1, 69K4, 69L1, 69Q1, 70V1
spallation [separation of a material or interface caused by stress-wave interactions] 66O1, 68F1	general 68E2, 70B4, 70H1
thermal mismatch 65S2, 68H2, 69T1, 70B1, 70B4, 70H2, 71B3, 71H2	
Test [used to determine degradation or failure]	
centrifuge 65C5, 65S2, 66G1, 67G1	
electron microprobe 67C2	
electrical parameter 67S2, 69P1	
metallurgical exam 59W1, 60W1, 65C3, 65C4, 65H1, 65H2, 66B3, 66B5, 69K3, 70P2	
pull 59W1, 60W1, 64S1, 65C4, 65C5, 65H1, 65H2, 66B4, 66G2, 66K1, 66R1, 67C3, 67R1, 67R2, 67S5, 67A3, 67L1, 68P1, 69B3, 69B5, 69L1, 69Q1, 69O2, 69P1, 70A2, 70B2, 70C1, 70P2, 70R1, 70V1, 71B4, 71G1, 71R1	
resistance 65H2, 65S2, 66B3, 66B5, 66G2, 66R1, 67C3, 67K2, 67L1, 67R1, 67R2, 67A3, 69K3, 70A2, 70B4, 70C1, 70R1, 71G2, 71L1	
shear 67A1, 67G1, 69L1	
temperature cycle 65C5, 66G1	
vibration (fatigue) 65C5	
vibration (variable frequency) 66G1	
visual inspection 65C3, 70C1	
visual inspection (SEM) 67A3, 67G1, 68P1, 69S1, 70A1, 70B8, 70D1, 70V1	

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TECHNIQUE FOR CONNECTING ELECTRICAL LEADS TO SEMICONDUCTORS
J. Appl. Phys., vol. 28, p. 923, Aug. 1957.
FABRICATION-bond: TC; wire: Ag, Al, Au, Cu; substrate: Ge, Si
Procedure
Schedule
Variables
Test: visual inspection
DESCRIPTIVE
- 57A2 Anderson, O. L.
ADHESION OF SOLIDS: PRINCIPLES AND APPLICATIONS
Bell Lab. Rec., vol. 35, pp. 441-445, Nov. 1957.
FABRICATION-bond: TC; wire: Ag, Al, Au, Cu, Pb, Pt, Sn; substrate: Ge, Si
Theory: TC
Evaluation: bond (adhesion)
DESCRIPTIVE
- 58C1 Christensen, H.
ELECTRICAL CONTACT WITH THERMO-COMPRESSION BONDS
Bell Lab. Rec., vol. 36, pp. 127-130, April 1958.
FABRICATION-bond: TC; wire: Ag, Al, Au; substrate: Ge, Si
Procedure
Variables
Test: pull
DESCRIPTIVE
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ULTRASONIC WELDING EQUIPMENT
IRE Intern. Conv. Record, vol. 7, pt. 6, pp. 204-212, 1959.
FABRICATION-bond: US
Theory: US
Schedule
Variables
Apparatus: design
Test: bond monitor; pull
DESCRIPTIVE
- 59J1 Jones, J. B., N. Maropis, J. G. Thomas, and D. Bancroft
FUNDAMENTALS OF ULTRASONIC WELDING-PHASE I
Final Rpt. (Dec. 1, 1957 to Dec. 1, 1958), Contract No. NOas 58-108c, May 1959. AD 235508 [summarized in 61J1].
FABRICATION-bond: US
- Theory: US
TEST-bond: US
Description: bond monitor
EXPERIMENTAL
- 59R1 Renaut, P.
APPARATUS FOR THE DETERMINATION OF THE EXISTENCE OR NON-EXISTENCE AND THE QUALITY OF A BONDING BETWEEN TWO PARTS OR MEMBERS
U.S. Patent 2,903,886; Sept. 15, 1959.
TEST
Description: ultrasonic probe
PATENT
- 59W1 Weare, N. E., J. N. Antonevich, R. E. Monroe, and D. C. Martin
RESEARCH AND DEVELOPMENT OF PROCEDURES FOR JOINING OF SIMILAR AND DISSIMILAR HEAT-RESISTING ALLOYS BY ULTRASONIC WELDING
Rpt. (July 1957 to June 1958), Contract No. AF 33(616)-5342, Feb. 1959. AD 208323 [summarized in 60W1].
FABRICATION-bond: US
Theory
Schedule
Variables
Apparatus: design
Tool: design
Bonding Surface: contamination; mechanical characteristics; preparation; topography
Test: bond monitor; metallurgical exam; pull
DEGRADATION-bond: US
Stress: process
Part: bond
Mechanism: fatigue; hardening
Test: metallurgical exam; pull
EXPERIMENTAL
- 60J1 Jones, J. B., N. Maropis, J. G. Thomas, and D. Bancroft
FUNDAMENTALS OF ULTRASONIC WELDING-PHASE II
Final Rpt. (Dec. 1, 1958 to Feb. 1, 1960), Contract No. NOas 59-6070-c, Dec. 1960. AD 257514.
FABRICATION-bond: US
Theory
Procedure
Schedule
Variables
Apparatus: description
Test: metallurgical exam; visual inspection
TEST-bond: US
Description: bond monitor
EXPERIMENTAL

60J2 Jones, J. B., W. C. Elmore and C. F. De Prisco
METHOD AND APPARATUS EMPLOYING VIBRATORY ENERGY FOR BONDING METALS
U.S. Patent 2,946,119; July 26, 1960.

FABRICATION-bond: US

Theory

Evaluation: US

Procedure

Variables

Apparatus: design

Test: metallurgical exam

PATENT

60W1 Wearne, N. E., J. N. Antonevich, and R. E. Monroe
FUNDAMENTAL STUDIES OF ULTRASONIC WELDING
Welding J., vol. 39 (supplement), pp. 331S-341S, Aug. 1960. [summary of 59W1]

FABRICATION-bond: US

Theory: US

Schedule

Variables

Apparatus: design

Tool: design

Bonding Surface: contamination; mechanical characteristics; preparation; topography

Test: metallurgical exam, pull

DEGRADATION-bond: US

Stress: process

Part: bond

Mechanism: hardening; fatigue

Test: metallurgical exam, pull

EXPERIMENTAL

61A1 Anderson, O. L. and H. Christensen
THERMO-COMPRESSION BONDING OF METAL TO SEMICONDUCTORS, AND THE LIKE
U.S. Patent 3,006,067; Oct. 31, 1961.

FABRICATION-bond: TC; wire: Ag, Al, Au, Au/Cu, Cu, Sn/Cu; substrate: Ge, Si

Theory

Procedure

Variables

Test: pull; visual inspection

PATENT

61A2 Ayre, R. S.
TRANSIENT RESPONSE TO STEP AND PULSE FUNCTIONS
Shock and Vibration Handbook, Volume 1 Basic Theory and Measurements
C. M. Harris and C. E. Crede, Eds., McGraw-Hill Book Co., Inc., New York, 1961, pp. 8-1 to 8-54.

TEST

Application: mechanical shock

THEORETICAL

61B1 Bernstein, L.
GOLD ALLOYING TO GERMANIUM, SILICON AND ALUMINUM-SILICON EUTECTIC SURFACES
PART 2
Semicond. Prod., vol. 4, pp. 35-39, Aug. 1961

DEGRADATION

Stress: thermal

Part: bond

Mechanism: intermetallics

EXPERIMENTAL

61D1 De Prisco, C. F.
METHOD AND APPARATUS FOR BONDING METALS
U.S. Patent 3,002,270; Oct. 3, 1961.

FABRICATION-bond: US

Evaluation: apparatus

Apparatus: adjustment

Test: shear

PATENT

61G1 Goetzberger, A.
INVESTIGATION OF CRYSTAL IMPERFECTIONS BY MEANS OF AVALANCHE BREAKDOWN PATTERNS OF VERY THIN DIFFUSED JUNCTIONS IN SILICON
International Conf. on Semiconductor Physics, Prague, 1960, Academic Press, New York, 1961, pp. 808-811.

DEGRADATION-bond: TC; wire: Au; substrate: Si

Stress: process

Part: substrate

EXPERIMENTAL

61J1 Jones, J. B., N. Maropis, J. G. Thomas, and D. Bancroft
PHENOMENOLOGICAL CONSIDERATIONS IN ULTRASONIC WELDING
Welding J., vol. 40 (supplement), pp. 289S-305S July 1961. [summary of 59J1]

FABRICATION-bond: US

Theory

Evaluation: US; metal system

Schedule

Variables

Test: bond monitor; bond temperature; metallurgical exam; photoelastic stress analysis; radiotracer

TEST-bond: US

Description: bond monitor

EXPERIMENTAL

62J1 Jones, J. B.
VIBRATORY WELDING PROCESS AND APPARATUS
U.S. Patent 3,056,192; Oct. 2, 1962.

TEST-bond: US

Description: bond monitor

PATENT

- 62M1 Matsuura, E., K. Matsui, and R. R. Hasiguti
TECHNIQUE FOR OHMIC CONNECTING LEADS TO SILICON
J. Appl. Phys., vol. 33, pp. 1610-1611, April 1962.
FABRICATION-bond: TC; wire: Ag, Au, Cu; film: Al, Bi, Ga, In, Sb; substrate: Ge, Si
Procedure
DESCRIPTIVE
- 62P1 Peterson, J. M., H. L. McKaig, and C. F. De Prisco
ULTRASONIC WELDING IN ELECTRONIC DEVICES
IRE Intern. Conv. Record, vol. 10, pt. 6, pp. 3-12, 1962.
FABRICATION-bond: US
Theory
Evaluation: US
Apparatus: description
DESCRIPTIVE
- 63L1 Longo, T. A. and B. Selikson
ALUMINUM WIRE BONDING OF SILICON TRANSISTORS
Semicond. Prod., vol. 6, pp. 27-31, Nov. 1963.
DEGRADATION-bond: TC; wire: Al, Au, Ag; film: Al, Au; substrate: Si, FeNiCo
Stress: process; thermal
Part: bond
Mechanism: intermetallics
ANALYTIC
- 63M1 McKinnon, M. C. and R. F. Hoeckelman
MECHANICAL AND ELECTRICAL PROPERTIES OF THERMOCOMPRESSION BONDS
IEEE Intern. Conv. Record, vol. 11, pt. 6, pp. 93-3, March 1963.
FABRICATION-bond: TC, wire: Al, Au, Cu, Pt, Ti, Zr; film: Al, Au/Al, Au/Cr, NiCr, Ta, Ti; substrate: Si
Theory
Evaluation: bond (adhesion)
Schedule
Variables
Apparatus: design
Test: pull; resistance; visual inspection
EXPERIMENTAL
- 63P1 Phillips, L. S.
THERMOCOMPRESSION BONDING TO THIN FILM MICROCIRCUITS
Brit. Commun. Electron., vol. 10, pp. 456-458, June 1963.
FABRICATION-bond: TC; wire: Au; film: Al/Cr, Au/Cr; substrate: ceramic, glass
Evaluation: TC; bond (adherence)
Schedule
Variables
- Bonding Surface: preparation; topography
Test: pull; resistance; temperature cycle; thermal shock; visual inspection
DESCRIPTIVE
- 63W1 Weiler, P. M., Ed.
PRODUCTION ENGINEERING MEASURE 2N914 AND 2N995
Final Rpt. (May 1, 1962-Oct. 31, 1963), Contact No. DA-36-039-SC-86726, Oct. 1963. AD 429 920
FABRICATION-bond: TC, US; wire: Ag, Al, Au, Pt; film: Ag, Ag/Al, Ag/Cr, Ag/Cr-Al, Al, Au, Au/Ag/Cr-Al, Au/Pt
Evaluation: TC; US; metal system (TC); tool (TC, US); wire (US)
Schedule: US
Variables: US
Apparatus: adjustment (TC); description (US); design (TC, US)
Tool: design (TC, US)
Wire: mechanical characteristics
Test: centrifuge, mechanical shock, pull, thermal shock, vibration (variable frequency)
TEST
Description: centrifuge; mechanical shock; pull; thermal shock; vibration (variable frequency)
DESCRIPTIVE
- 64A1 Arle, W. K.
FABRICATION TECHNIQUE FOR OPTIMUM THERMOCOMPRESSION BONDS
IEEE Trans. Component Parts, vol. CP-10, pp. 25-29, Dec. 1964
FABRICATION-bond: TC; wire: Ag, Al, Au; substrate: Si
Theory
Schedule
Variables
Test: shear
EXPERIMENTAL
- 64C1 Cohn, A.
GOLD BONDING WIRES
Semicond. Prod. Solid State Technol., vol. 7, pp. 18-20, July 1964.
FABRICATION-wire: Au, Au/Ni, Au/Pt, Au/W
Wire: care; mechanical characteristics
DESCRIPTIVE
- 64C2 Clunie, J. M. and N. H. Rock
THE LASER FEEDBACK INTERFEROMETER
J. Sci. Instruments, vol. 41, pp. 489-492, Aug. 1964.
TEST-bond: US
Application: bond monitor
EXPERIMENTAL

64D1 Davidson, K. W.
RELIABILITY IMPROVEMENT PROCESS EVALUATION
Proc. Conf. on Reliability of Semiconductor Devices and Integrated Circuits, vol. 1, sect. 14, pp. 14.1-14.34, June 1964. AD 645221

FABRICATION-bond: TC; wire: Al; film: Al, Au
Evaluation: bond (stitch)

TEST-bond: TC; wire: Al

Evaluation: pull (nondestructive)

DESCRIPTIVE

64D2 De Prisco, C. F. and W. M. Barfield
METHOD AND MEANS FOR OPERATING A GENERATING MEANS COUPLED THROUGH A TRANS-DUCER TO A VIBRATORY ENERGY WORK PERFORMING DEVICE

U.S. Patent 3,158,928; Dec. 1, 1964.

FABRICATION-bond: US

Apparatus: adjustment

PATENT

64H1 Hill, P.
UNIFORM METAL EVAPORATION
Proc. Conf. on Reliability of Semiconductor Devices and Integrated Circuits, vol. 2, sect. 27, pp. 27.1-27.10, June 1964. AD 645222

FABRICATION-bond: TC; wire: Au; film: Al
Bonding Surface: film thickness; preparation
EXPERIMENTAL

64H2 Howell, J. R. and J. W. Slemmons
EVALUATION OF THERMOCOMPRESSION BONDING PROCESSES
Presented to 9th Welded Electric Packaging Association Symposium, Santa Monica, California, Feb. 27, 1964; Autonetics Report No. T4-240/3110, March 1964. (13)

FABRICATION-bond: TC; wire: Au; film: Al, Pt; substrate: Si

Procedure

Schedule

Variables

Control: temperature

Tool: design

Bonding Surface: contamination; topography

Test: pull

TEST-bond: TC

Evaluation: visual inspection

REVIEW

64J1 Johnson, W. G.
LEAD BONDING MACHINE
U.S. Patent 3,125,906; March 24, 1964.

FABRICATION-bond: TC

Apparatus: design

PATENT

64M1 Myers, D. K.
SMALL BALL BONDING
Proc. Conf. on Reliability of Semiconductor Devices and Integrated Circuits, vol. 2, sect. 28, pp. 28.1-28.6, June 1964. AD 645222

FABRICATION-bond: TC; wire: Au; film: Al

Evaluation: bond (ball); tool

Procedure

Apparatus: design

Test: centrifuge; mechanical shock; thermal shock; vibration (variable frequency)

DESCRIPTIVE

64P1 Partridge, J., L. D. Hanley and E. C. Hall
PROGRESS REPORT ON ATTAINABLE RELIABILITY OF INTEGRATED CIRCUITS FOR SYSTEMS APPLICATION
Symp. on Microelectronics and Large Systems, Washington, D. C., cosponsored by ONR and UNIVAC, Nov. 1964. (12)

DEGRADATION-bond: TC; wire: Au; film: al

Stress: process; test (centrifuge)

Part: wire; bond

Mechanism: intermetallics

DESCRIPTIVE

64S1 Selikson, B., and T. A. Longo
A STUDY OF PURPLE PLAGUE AND ITS ROLE IN INTEGRATED CIRCUITS
Proc. IEEE, vol. 52, pp. 1638-1641, Dec. 1964.

DEGRADATION-bond: TC; wire: Al, Au; film: Al, Au; substrate: FeNiCo, Si

Stress: thermal

Part: bond

Mechanism: intermetallics

Test: pull

FABRICATION-wire: Al, Au; film: Ag/Cr, Al, Au, Cr/Al, Pl, Pt

Evaluation: metal system

DESCRIPTIVE

64U1 Univac
FINAL REPORT FOR INTEGRATED CIRCUIT STUDY
Contract No. NObsr 89341, Aug. 1964. AD 605432

DEGRADATION-bond: TC; wire: Al, Au; film: Al, Au

Stress: process; test (centrifuge, mechanical shock, thermal shock); thermal

Part: wire; bond; metallization

Mechanism: intermetallics

Failure Rates

EXPERIMENTAL

- 64W1** Worlton, D. C. and R. A. Walker
**METHOD AND DEVICE FOR CONTROLLING
 ULTRASONIC WELDING APPARATUS**
 U.S. Patent 3,153,850; Oct. 27, 1964.
TEST-bond: US
Description: bond monitor
PATENT
- 65B1** Baker, D. and I. E. Bryan
**AN IMPROVED FORM OF THERMOCOMPRESSION
 BOND**
 Brit. J. Appl. Phys., vol. 16, pp. 865-
 871, June 1965. [similar to 66B4]
FABRICATION-bond: TC; wire: Al, Au; film: Al,
 Au; substrate: FeNiCo
Evaluation: bond (ball, wedge); tool; wire
Schedule: TC
Tool: design
Bonding Surface: contamination
Test: centrifuge, pull, pull (nondestructive)
TEST-bond: TC
Description: pull (nondestructive)
Correlation: centrifuge; pull
DESCRIPTIVE
- 65C1** Cohen, J.
**PLATINUM-SILICON THERMO-COMPRESSION
 BONDS**
 Solid State Electron., vol. 8, p. 79,
 Jan. 1965.
FABRICATION-bond: TC; wire: Pt; substrate: Si
Procedure
DESCRIPTIVE
- 65C2** Cummings, D. G.
**IDENTIFICATION OF THERMAL COMPRESSION
 BOND FAILURES**
 IEEE WESCON Convention Record, vol. 9,
 Session 16B.1, pp. 1-3, July 1965. [2]
TEST-bond: TC; wire: Au; film: Al
Precaution: resistance
DESCRIPTIVE
- 65C3** Colteryahn, L. E. and D. D. Shaffer
**CHARACTERIZATION OF FAILURE MODES IN
 GOLD-ALUMINUM THERMOCOMPRESSION BONDS**
 IEEE WESCON Convention Record, vol. 9,
 Session 16B.2, pp. 1-8, July 1965. [2]
DEGRADATION-bond: TC; wire: Au; film: Al
Stress: thermal
Part: bond
Mechanism: intermetallics
Test: metallurgical exam; visual inspection
DESCRIPTIVE
- 65C4** Colteryahn, L. E. and J. F. Kersey
**FAILURE MECHANISMS AND KINETICS OF IN-
 TERMETALLIC FORMATION**
- IEEE WESCON Convention Record, vol. 9,
 Session 16B.3, pp. 1-10, July 1965. [2]
DEGRADATION-bond: TC; wire: Au; film: Al
Stress: thermal
Part: bond
Mechanism: intermetallics
Test: metallurgical exam; pull
EXPERIMENTAL
- 65C5** Cunningham, J. A.
**EXPANDED CONTACTS AND INTERCONNECTIONS
 TO MONOLITHIC SILICON INTEGRATED CIR-
 CUICTS**
 Solid State Electron, vol. 8, pp. 735-
 745, April 1965.
FABRICATION-bond: TC; wire: Au; film: Al, Au,
 Au/Ag, Au/Co, Au/Cr, Au/Mo, Au/Ni;
 substrate: Si
Evaluation: metal system; metallization
Bonding Surface: film thickness
Test: pull
DEGRADATION-bond: TC; wire: Al, Au; film: Al,
 Au, Au/Mo
Stress: thermal
Part: bond
Mechanism: intermetallics
Test: centrifuge; pull; temperature cycle;
 vibration (fatigue)
ANALYTIC
- 65D1** Daniels, H. P. C.
ULTRASONIC WELDING
 Ultrasonics, vol. 3, pp. 190-196, Oct.-
 Dec. 1965
FABRICATION-bond: US; wire: Al, Au; substrate:
 Ge, glass, Si
Theory
Variables
Apparatus: design
Tool: design
Bonding Surface: topography
REVIEW
- 65H1** Howell, J. R.
**INFLUENCE OF BONDING VARIABLES ON AU/AL
 TC BOND FAILURE**
 Proc. Second Physics of Failure Col-
 loquim (CQAP), pp. 71-79, June 4,
 1965, presented on March 29, 1965
 at North American Aviation, Inc.,
 Autonetics, Anaheim, California
 92803, [similar to 65H2] (13)
FABRICATION-bond: TC; wire: Au; film: Al;
 substrate: glass
Variables
Control: temperature
Bonding Surface: film thickness; preparation
Test: pull
DEGRADATION-bond: TC; wire: Au; film: Al; sub-
 strate: glass

65H1 (cont.)

Stress: thermal
Part: wire; bond
Mechanism: intermetallics
Test: metallurgical exam; pull
EXPERIMENTAL

65H2 Howell, J. R. and J. W. Kanz
TIME-TEMPERATURE EFFECTS ON GOLD-
ALUMINUM THERMOCOMPRESSION BONDS
IEEE WESCON Convention Record, vol. 9,
Session 16B.4, pp. 1-19, July 1965. [2]
FABRICATION-bond: TC; wire: Au, film: Al;
substrate: glass

Variables

Control: temperature
Bonding Surface: film thickness; preparation
Test: pull; metallurgical exam
DEGRADATION-bond: TC; wire: Au; film: Al;
substrate: glass
Stress: thermal
Part: wire; bond
Mechanism: intermetallics
Test: metallurgical exam; pull; resistance
EXPERIMENTAL

65H3 Hakim, E. B. and B. Reich
U.S. ARMY ADVANCEMENT IN TRANSISTOR
RELIABILITY THROUGH MANUFACTURING
PROCESS IMPROVEMENTS
IEEE Trans. Reliability, vol. R-14,
pp. 94-99, Oct. 1965. [see p. 98]

TEST

Evaluation: thermal shock
DESCRIPTIVE

65J1 Jones, J. B., G. W. Fable, A. L.
Jamieson, E. F. Nippes, N. E. Promisel,
F. N. Rhines, and R. K. Sager
ULTRASONIC WELDING
Welding Handbook, A. L. Phillips, Ed.,
American Welding Society, New York,
1965, Chapt. 49, pp. 1-48. [8]

FABRICATION-bond: US

Theory

Procedure

Schedule

Variables

Apparatus: design

Test: bond monitor; metallurgical exam; pull
REVIEW

65K1 Kramer, I. R.
EFFECT OF SURFACES ON MECHANICAL
BEHAVIOR OF METALS
Proc. 3rd Symp. on Fundamental Phenom-
ena in the Materials Sciences, Boston,
Mass.; vol. 3, pp. 171-193, Jan. 1965.

FABRICATION

Wire: contamination; mechanical character-
istics; topography

DEGRADATION

Part: wire

Mechanism: fatigue

ANALYTIC

65M1 Maki, C. E., F. W. Hagert, H. J. Avil,
L. Kirvida, M. N. Asmus, W. T. Sackett,
Jr., C. R. Seashore
DETECTION OF ELECTRICAL FAULTS BY
R. F. TECHNIQUES
Mater. Eval., vol. 23, pp. 285-291,
June 1965.

TEST

Description: noise

EXPERIMENTAL

65N1 Neppiras, E. A.
ULTRASONIC WELDING OF METALS
Ultrasonics, vol. 3, pp. 128-135,
July-Sept. 1965.

FABRICATION-bond: US

Theory

Procedure

Variables

Apparatus: design

DESCRIPTIVE

65R1 Ruggiero, E. M.
ALUMINUM BONDING IS KEY TO 40-WATT
MICROCIRCUITS
Electronics, vol. 38, pp. 98-104,
Aug. 23, 1965.

FABRICATION-bond: TC; wire: Al, Au; film:
Al, Au

Evaluation: bond (ball, stitch, wedge);
wire

Procedure

Test: centrifuge; mechanical shock; vibration
(variable frequency)

DEGRADATION-bond: TC; wire: Al, Au; film:
Al, Au

Stress: thermal

Part: bond

Mechanism: intermetallics

DESCRIPTIVE

65R2 Ruggiero, E. M.
GOLD-ALUMINUM ADHESION AND REACTION
ON SEMICONDUCTOR SURFACES
Proc. IEEE Annual Microelectronics
Symp., pp. 6B-1 to 6B-4, May 1965.
[2] (14)

DEGRADATION-bond: TC; wire: Au; film: Al;
substrate: alumina, BN, glass, Si

Stress: process; thermal

Part: bond

Mechanism: intermetallics

65R2 (cont.)

FABRICATION-film: Al; substrate: alumina, BN, glass, Si
Evaluation: metal system; wire
Bonding Surface: preparation
ANALYTIC

65S1 Slemmons, J. W. and J. R. Howell
BETTER BONDING METHODS IMPROVE HYBRID CIRCUITS
Electronics, vol. 38, pp. 86-92, March 22, 1965.

FABRICATION-bond: TC; wire: Au; film: Al, Au/NiCr, Cu/NiCr; substrate: alumina, Si

Procedure
Control: temperature
Test: pull
DESCRIPTIVE

65S2 Soltau, R.
FAILURE MODES AND MECHANISMS IN MICRO-ELECTRONIC DEVICES
Seminar on Reliability in Space Vehicles, Los Angeles, Calif., April 2, 1965. (15)

DEGRADATION-bond: TC; wire: Au; film: Al, Au; substrate: Si
Stress: process; test (centrifuge); thermal
Part: wire; bond; metallization; substrate
Mechanism: contamination; corrosion; intermetallics; thermal mismatch
Test: centrifuge; resistance
DESCRIPTIVE

65S3 Szasz, P. R.
BIND-BEAK WIRE BONDING INSTRUMENT FOR THERMOCOMPRESSIVELY SECURING LEADS TO SEMICONDUCTOR DEVICES
U.S. Patent 3,216,640; Nov. 9, 1965.
FABRICATION-bond: TC
Apparatus: design
Tool: design
PATENT

65W1 Wasson, R. D.
THERMOCOMPRESSION BOND TESTER
Proc. IEEE, vol. 53, pp. 1736-1737, Nov. 1965.

TEST
Description: pull
DESCRIPTIVE

66A1 Antle, W. K.
DETERMINING THERMOCOMPRESSION BONDING PARAMETERS BY A FRICTION TECHNIQUE

Trans. Met. Soc. AIME, vol. 236, pp. 392-396, March 1966. [similar to 64A1]

FABRICATION-bond: TC; wire: Ag, Al, Au; film: Al, Au, Ni; substrate: Si

Theory
Schedule
Variables
Test: shear
EXPERIMENTAL

66A2 Angelucci, T. L. and F. W. Kulicke, Jr.
NAIL HEAD BONDING APPARATUS FOR THERMOCOMPRESSIVELY SECURING LEAD WIRE TO SEMI-CONDUCTOR DEVICES
U.S. Patent 3,250,452; May 10, 1966.

FABRICATION-bond: TC
Procedure
Apparatus: design
PATENT

66B1 Bagrowski, J., S. G. Konsowski, Jr., and G. D. Spencer
INTERCONNECTION OF MONOLITHIC INTEGRATED CIRCUITS THROUGH THE USE OF ADVANCED MATERIALS AND TECHNIQUES
IEEE Trans. Pts. Materials Packaging, vol. PHP-2, pp. 90-98, Dec. 1966.

FABRICATION-bond: TC, US
Evaluation: TC, US
Variables: TC, US
DESCRIPTIVE

66B2 Browning, G. V.
FAILURE MECHANISMS IN MICROCIRCUITS
Proc. Second Int. Symp. on Microelectronics, pp. 485-516, Munich, Germany, Oct. 1966. (13)

DEGRADATION-bond: TC; wire: Au; film: Al
Stress: process
Part: wire; bond
Mechanism: intermetallics
Failure Rates
DESCRIPTIVE

66B3 Blech, I. A. and H. Sello
SOME NEW ASPECTS OF GOLD-ALUMINUM BONDS
J. Electrochem. Soc., vol. 113, pp. 1052-1054, Oct. 1966.

DEGRADATION-bond: TC; wire: Au; film: Al
Stress: thermal
Part: bond
Mechanism: intermetallics
Test: metallurgical exam; resistance
FABRICATION-bond: TC; wire: Au; film: Al
Bonding Surface: film thickness
ANALYTIC

- 66B4 Baker, D. and R. Jones
NEW DEVELOPMENTS IN THERMOCOMPRESSION BONDING
 Microelectronics and Reliability, vol. 5, pp. 229-234, Aug. 1966. [similar to 65B1]
 FABRICATION-bond: TC; wire: Al, Au; film: Al, Au; substrate: Al, FeNiCo, Si
 Theory
 Evaluation: bond (ball, wedge); tool
 Tool: design
 Bonding Surface: contamination
 Test: pull, pull (nondestructive)
 DEGRADATION-bond: TC; wire: Al; film: Au; substrate: FeNiCo
 Stress: thermal
 Part: wire; bond
 Mechanism: intermetallics
 Test: pull
 TEST-bond: TC; wire: Al
 Description: pull (nondestructive)
 DESCRIPTIVE
- 66B5 Browning, G. V., L. E. Colteryahn and D. G. Cummings
FAILURE MECHANISMS ASSOCIATED WITH THERMOCOMPRESSION BONDS IN INTEGRATED CIRCUITS
Physics of Failure in Electronics, vol. 4, RADC Series in Reliability, M. E. Goldberg and J. Vaccaro, Eds., 1966, pp. 428-446. AD 637529
 DEGRADATION-bond: TC; wire: Au; film: Al
 Stress: process; thermal
 Part: bond
 Mechanism: intermetallics
 Test: metallurgical exam; resistance
 DESCRIPTIVE
- 66B6 Bikerman, J. J.
SOLID TO SOLID ADHESION
 Symposium on Fundamental Phenomena in the Materials Sciences, 2nd, Boston, 1964. Surface phenomena. L. J. Bonis and H. H. Hausner, Ed. "Fundamental Phenomena in the Materials Sciences, vol. 2", Plenum Press, New York, 1966, pp. 165-174.
 FABRICATION-bond: TC, US
 Theory
 DESCRIPTIVE
- 66B7 Brandewie, G. V., P. H. Eisenberg, and R. A. Meyer
INVESTIGATION OF SURFACE FAILURE MECHANISMS IN SEMICONDUCTOR DEVICE BY ENVELOPE AMBIENT STUDIES
Physics of Failure in Electronics, vol. 4, M. E. Goldberg and J. Vaccaro, Eds., RADC Series in Reliability, 1966, pp. 493-521. AD 637529. [see pp. 510-516]
 DEGRADATION-film: Al
 Stress: moisture
 Part: metallization
 Mechanism: corrosion
 EXPERIMENTAL
- 66C1 Conti, R. J.
THERMOCOMPRESSION JOINING TECHNIQUES FOR ELECTRONIC DEVICES AND INTERCONNECTS
 Metals Eng. Quart., vol. 6, pp. 29-35, Feb. 1966.
 FABRICATION-bond: TC; wire: Ag, Au, Au/Cu, Cu/Ni; substrate: alumina, glass
 Evaluation: TC
 Schedule
 Variables
 Control: temperature
 Tool: design
 Wire: size
 Bonding Surface: contamination
 Test: pull; thermal shock
 DESCRIPTIVE
- 66C2 Clews, K. J. and J. G. Young
METALLURGICAL EVALUATION OF MICROCIRCUIT INTERCONNECTIONS MADE BY THE PARALLEL-GAP PROCESS
 Microelectronics and Reliability, vol. 5, pp. 207-208, Aug. 1966.
 FABRICATION
 Evaluation: bond
 Test: metallurgical exam
 DESCRIPTIVE
- 66E1 Eimbinder, J.
LINEAR INTEGRATED CIRCUITS
 EEE, vol. 14, pp. 76-86, Nov. 1966.
 FABRICATION-bond: TC, US
 Evaluation: TC; US; bond (ball, stitch, wedge)
 DESCRIPTIVE
- 66G1 Go, H. T., N. J. McAfee and H. C. Jones
MICROELECTRONICS RELIABILITY FROM A SYSTEM MANUFACTURER'S POINT OF VIEW
 Second Int. Symp. on Microelectronics; Munich, Germany, Oct. 1966. (16)
 DEGRADATION
 Stress: process
 Part: wire; bond
 Mechanism: contamination; intermetallics
 Test: centrifuge; thermal cycle; vibration (variable frequency)
 DESCRIPTIVE

- 66G2 Gianelle, W. H.
ANALYSIS OF SEVEN SEMICONDUCTOR METAL-
LURGY SYSTEMS USED ON SILICON PLANAR
TRANSISTORS
Physics of Failure in Electronics,
vol. 4, M. E. Goldberg and J. Vaccaro,
Eds., RADC Series in Reliability, 1966,
pp. 46-57. AD 637529
FABRICATION-bond: TC; wire: Ag, Al, Au; film:
Ag, Ag/Cr, Al, Au, Au/Mo
Evaluation: bond (ball, wedge); metal sys-
tem; wire
Bonding Surface: film thickness
Test: pull; resistance
DEGRADATION-bond: TC; wire: Au; film: Al
Stress: thermal
Part: wire; bond
Mechanism: grain growth; intermetallics
Test: pull; resistance
ANALYTIC
- 66H1 Hammond, V. J.
THIN-FILM PREPARATION IN RELATION TO
MICROBONDING
Microelectronics and Reliability, vol.
5, pp. 213-217, Aug. 1966.
FABRICATION-bond: TC, US; film: Al, Al/Cr,
Au, Au/Cr; substrate: ceramic, glass
Evaluation: metallization
Bonding Surface: preparation
DESCRIPTIVE
- 66I1 IEC
BASIC ENVIRONMENTAL TESTING PROCEDURES
FOR ELECTRONIC COMPONENTS AND ELEC-
TRONIC EQUIPMENT PART 2: TESTS-
TEST F: VIBRATION
IEC Recommendation, publication
68-2-6 (1966) and supplements
68-2-6A, 68-2-6B and 68-2-6C;
1966-1969. [3]
TEST
Description: vibration (variable frequency,
fatigue
STANDARD
- 66K1 Khorouzan, M. and L. Thomas
CONTAMINATION OF ALUMINUM BONDS IN IN-
TEGRATED CIRCUITS
Trans. Met. Soc. AIME, vol. 236,
pp. 397-405, March 1966.
DEGRADATION-bond: US; wire: Al; film: Al;
substrate: FeNiCo
Stress: process; test (thermal cycle); ther-
mal
Part: wire; bond
Mechanism: anneal; contamination; grain
growth
Test: pull
ANALYTIC
- 66K2 Koedam, M.
DETERMINATION OF SMALL DIMENSIONS BY
DIFFRACTION OF A LASER BEAM
Philips Tech. Rev., vol. 27, pp. 208-
212, Nov. 2, 1966.
FABRICATION
Wire: size
DESCRIPTIVE
- 66K3 Köllner, H.
METHOD AND DEVICE FOR BONDING A CON-
TACT WIRE TO A SEMICONDUCTOR MEMBER
U.S. Patent 3,289,452; Dec. 6, 1966.
FABRICATION-bond: TC
Apparatus: design
PATENT
- 66L1 Larson, R. B.
MICROJOINING PROCESSES FOR ELECTRONIC
PACKAGING PART 3
Assembly Engineering, vol. 9, pp. 30-
33, Nov. 1966. (17)
FABRICATION-bond: TC; wire: Au
Evaluation: bond (ball, stitch, wedge); tem-
perature control
Procedure
Variables
Control: temperature
DESCRIPTIVE
- 66L2 Landis, D.
CATASTROPHIC FAILURES IN SEMICONDUCTOR
DEVICES EXPOSED TO PULSED RADIATION
IEEE Trans. Nucl. Sci., vol. NS-13,
pp. 591-600, June 1966.
DEGRADATION-bond: TC; wire: Au
Stress: radiation
Part: bond
ANALYTIC
- 66L3 Langenecker, B.
EFFECTS OF ULTRASOUND ON DEFORMATION
CHARACTERISTICS OF METALS
IEEE Trans. Sonics Ultrason., vol. SU-13,
pp. 1-8, March 1966.
FABRICATION-bond: US
Wire: mechanical characteristics
DEGRADATION-bond: US
Stress: process
Part: wire
Mechanism: hardening
REVIEW

66L4 Lombardi, J., L. McDonough, H. Padden
**HIGH RELIABILITY SCREENING OF SEMI-
CONDUCTOR AND INTEGRATED CIRCUIT
DEVICES**

Final Rpt., Contract MAS 5-9639, Sept.
1966. N67-16772

TEST

Description: centrifuge; temperature cycle;
vibration (monitored, variable fre-
quency); visual inspection; x-ray

Evaluation: centrifuge; temperature cycle;
vibration (monitored, variable fre-
quency); visual inspection; x-ray

DESCRIPTIVE

66M1 Mann, R. M.
**BAD WELD DETECTOR USES INTEGRATED
CIRCUITS**

EDN, vol. 11, pp. 108-112, July 1966.

TEST

Description: resistance

DESCRIPTIVE

66O1 Oswald, K. B., Jr.
**FRACTURE OF SILICON AND GERMANIUM
INDUCED BY PULSED ELECTRON IRRADIATION**

IEEE Trans. Nucl. Sci., vol. NS-13,
pp. 63-69, Dec. 1966.

DEGRADATION

Stress: radiation

Part: substrate

Mechanism: spallation

EXPERIMENTAL

66P1 Partridge, J., E. C. Hall, and L. D.
Hanley
**THE APPLICATION OF FAILURE ANALYSIS IN
PROCURING AND SCREENING OF INTEGRATED
CIRCUITS**

Physics of Failure in Electronics,
vol. 4, M. E. Goldberg and J. Vaccaro,
Eds., RADC Series in Reliability, 1966,
pp. 95-139. AD 637529

TEST

Description: centrifuge; vibration (variable
frequency); mechanical shock; Mil-Std-
750; temperature cycle; visual inspec-
tion

Screening Procedures

DESCRIPTIVE

66R1 Riben, A. R., and S. L. Sherman
**MICROBONDS FOR HYBRID MICROCIRCUITS
PROGRESS REPORT**

Rpt. 8 (Nov. 1, 1965-Jan. 31, 1966),
Contract No. DA 36-039 AMC-03742 (E),
May 20, 1966. AD 633723 [summarized
in 67L1]

FABRICATION-bond: US; wire: Al, film: Au/Cr;
substrate: alumina, beryllia, sapphire

Evaluation: US

Schedule

Wire: mechanical characteristics

Bonding Surface: film thickness; topography

Test: pull; resistance

DEGRADATION-bond: US; wire: Al; film: Au/Cr;
substrate: alumina, beryllia, sapphire

Stress: thermal

Part: metallization

Test: pull, resistance

TEST-bond: US; wire: Al; film: Au/Cr; sub-
strate: alumina, beryllia, sapphire

Correlation: pull; resistance

EXPERIMENTAL

66W1 Wagner, R.
**SEMICONDUCTOR DEVICES WITH SILVER-
GOLD LEAD WIRES ATTACHED TO ALUMINUM
CONTACTS**

U.S. Patent 3,271,635, Sept. 6, 1966.

FABRICATION: wire: Au, Au/Ag; film: Al

Evaluation: metal system; wire

Test: pull

DEGRADATION

Mechanism: intermetallics

PATENT

67A1 Arleth, J. M. and R. D. Demenus
**NEW TEST FOR THERMOCOMPRESSION MICRO-
BONDS**

Electron. Prod., vol. 9, pp. 92, 94,
May 1967.

TEST-bond: TC; wire: Au; film: Al, Au

Description: shear

DEGRADATION-bond: TC; wire: Au; film: Al, Au

Stress: thermal

Part: bond

Mechanism: intermetallics

Test: shear

DESCRIPTIVE

67A2 Avedissian, M. K.
THERMOCOMPRESSION BONDING APPARATUS

U.S. Patent 3,313,464, April 11, 1967.

FABRICATION-bond: TC

Procedure

Apparatus: design

PATENT

67A3 Anstead, R. J.
**FAILURE ANALYSIS USING A SCANNING
ELECTRON MICROSCOPE**

Proc. 6th Annual Reliability Physics
Symposium, Los Angeles, Calif. pp.
127-137, Nov. 1967. [2]

DEGRADATION-bond: TC, US; wire: Al, Au; film:
Al

Stress: process

Part: wire; bond

Mechanism: intermetallics

Test: visual inspection (SEM)

DESCRIPTIVE

- 67B1 Bobo, S. N.
MICROELECTRIC WELDING - AN APPROACH TO IMPROVED RELIABILITY
 Proc. SAE Electronic Packaging Conf.
 New York, N. Y., pp. 6-12, Feb. 1967.
- TEST
 Description: IR Monitor
 DESCRIPTIVE
- 67B2 Beadles, R. L.
INTEGRATED SILICON DEVICE TECHNOLOGY VOLUME XIV
 Rpt. (Jan. 1966-March 1967), Contract AF 33 (615)-3305, May 1967. AD 654630. [see pp. 23-48]
 FABRICATION-bond: TC, US; wire: Al, Au; film: Al, Al/Cr, Au, Au/Cr
 Theory: TC, US
 Evaluation: US, TC; bond (ball, stitch, wedge)
 Procedure: TC, US
 Schedule: TC
 Variables: TC
 Apparatus: description (US)
 Tool: design (TC)
 Wire: care
 DEGRADATION
 Mechanism: intermetallics
 REVIEW
- 67B3 Blech, I. A., and H. Sello
THE FAILURE OF THIN ALUMINUM CURRENT-CARRYING STRIPS ON OXIDIZED SILICON
Physics of Failure in Electronics, vol. 5, T. S. Shilliday and J. Vaccaro, Eds., RADC Series in Reliability, 1967, pp. 496-505. AD 655397
 DEGRADATION-bond: TC; wire: Au; film: Al
 Stress: electrical; thermal
 Part: bond
 Mechanism: electromigration; intermetallics
 DESCRIPTIVE
- 67B4 Bayer, R. G. and T. S. Burke
APPLICATION OF THE ULTRASONIC RESONANCE TECHNIQUE TO INSPECTION OF MINIATURE SOLDERED AND WELDED JUNCTIONS
 Mater. Eval., vol. 25, pp. 20-24, Jan. 1967.
- TEST
 Description: US probe
 DESCRIPTIVE
- 67C1 Cunningham, J. A. and J. G. Hayser
SEMICONDUCTOR RELIABILITY: FOCUS ON THE CONTACTS
 EE, vol. 26, pp. 74-79, Jan. 1967.
 FABRICATION-bond: TC; wire: Al, Au; film: Al, Au/Mo, Au/Mo/Pt
 Evaluation: metallization; bond (ball, wedge)
- Bonding Surface: metal system; preparation
 DEGRADATION-bond: TC; wire: Al, Au; film: Al, Au/Mo, Au/Mo/Pt
 Stress: thermal
 Part: bond
 Mechanism: corrosion; intermetallics
 DESCRIPTIVE
- 67C2 Cline, J. E. and S. Schwartz
ELECTRON MICROPROBE TECHNIQUES FOR FAILURE ANALYSIS OF SILICON PLANAR DEVICES
 Proc. 6th Annual Reliability Physics Symposium, Los Angeles, Calif. pp. 193-200, Nov. 1967. [2]
 DEGRADATION
 Stress: process
 Part: bond
 Mechanism: contamination
 Test: electron microprobe
 DESCRIPTIVE
- 67C3 Chen, G. K. C.
ON THE PHYSICS OF PURPLE PLAGUE FORMATION, AND THE OBSERVATION OF PURPLE PLAGUE IN ULTRASONICALLY JOINED GOLD-ALUMINUM BOND
 IEEE Trans. Pts. Material Packaging, vol. PMP-3, pp. 149-153, Dec. 1967.
 DEGRADATION-bond: US; wire: Au; film: Al
 Stress: thermal
 Part: bond
 Mechanism: intermetallics
 Test: pull; resistance
 TEST-bond: US; wire: Au; film: Al
 Correlation: pull, resistance
 ANALYTIC
- 67C4 Cunningham, J. A.
THE PLAGUES IN SEMICONDUCTOR CONTACTS
 EE, vol. 26, p. 39, April 1967.
 DEGRADATION
 Mechanism: intermetallics
 REVIEW
- 67G1 Gill, W. L. and W. Workman
RELIABILITY SCREENING PROCEDURES FOR INTEGRATED CIRCUITS
Physics of Failure in Electronics, vol. 5, RADC Series in Reliability, T. S. Shilliday and J. Vaccaro, Eds., 1967, pp. 101-141. AD 655397
 DEGRADATION-bond: TC; wire: Au; film: Au/Mo
 Stress: process; test (centrifuge, thermal shock); thermal
 Part: wire; bond; metallization; substrate
 Mechanism: contamination
 Test: centrifuge; shear; visual inspection
 Failure Rates
 TEST-bond: TC; wire: Au; film: Au/Mo

67G1 (cont.)

Evaluation: centrifuge; shear; visual inspection; x-ray

Screening Procedures

FABRICATION

Evaluation: package

DESCRIPTIVE

67G2 Graham, R. A. and R. E. Hutchison
THERMOELASTIC STRESS PULSES RESULTING
FROM PULSED ELECTRON BEAMS
Appl. Phys. Lett., vol. 11, pp. 69-72,
July 15, 1967.

TEST

Application: mechanical shock (radiation-induced)

ANALYTIC

67H1 Higbie, T. E.
THERMOCOMPRESSION BONDING OF GOLD WIRE
FOR MICROELECTRONIC CIRCUITS
Report No. NAFI-TR-1108, Oct. 1967.
AD 671879

FABRICATION-bond: TC; wire: Au; film: Al, Au

Procedure

Schedule

Variables

Apparatus: adjustment

Test: pull

TEST-bond: TC; wire: Au; film: Au

Description: pull

DESCRIPTIVE

67H2 Haigler, E. D.
ULTRASONIC SCISSORS BONDING INSTRUMENT
U S. Patent 3,314,582; April 18, 1967.

FABRICATION-bond: US

Apparatus: design

PATENT

67I1 IEC
BASIC ENVIRONMENTAL TESTING PROCEDURES
FOR ELECTRONIC COMPONENTS AND ELECTRONIC
EQUIPMENT PART 2: TESTS -
TEST EA: SHOCK
IEC Recommendation, publication 68-2-27
and supplement 68-2-27A; 1967-1968. [3]

TEST

Description: mechanical shock

STANDARD

67J1 Jones, J. B.
ULTRASONIC WELDING
Proc. CIRP Int. Conf. on Mfg. Technol.,
sponsored by ASTM, pp. 1387-1409,
Sept. 1967. (18)

FABRICATION-bond: US

Theory

Schedule

Variables

Apparatus: design

Test: bond monitor, metallurgical exam

REVIEW

67K1 Koshinz, E. F.
THERMOCOMPRESSION BONDING - AN OVERVIEW
Proc. 1967 Welding Congress, pp. 86-94,
Stuttgart, Germany, 1967. [In German]
(19)

FABRICATION-bond: TC; wire: Al, Au; film:
Ag/Cr, Al, Au, Au/Mo/Pt

Evaluation: bond (ball, wedge); metal system;
temperature control

Procedure

Variables

Test: centrifuge; pull

DEGRADATION-bond: TC; wire: Au; film: Al

Mechanism: intermetallics

REVIEW

67K2 Keen, R. S., L. R. Loewenstern and
G. L. Schnable
MECHANISMS OF CONTACT FAILURES IN
SEMICONDUCTOR DEVICES
Proc. 6th Annual Reliability Physics
Symp. Los Angeles, Calif., pp. 216-233,
Nov. 1967. [2]

DEGRADATION-bond: TC; wire: Au; film: Al

Stress: thermal

Part: bond

Mechanism: intermetallics

Test: resistance

REVIEW

67L1 Lane, W. V.
MATERIALS FOR CONDUCTIVE ELEMENTS PART
II - CONNECTIONS TO THIN FILMS
IEEE Intern. Conv. Record, vol. 15,
pt. 7, pp. 129-145, 1967. [summary of
66R1, 67R2]

FABRICATION-bond: US; wire: Al; film: Al,
Au/Cr, substrate: alumina, beryllia,
glass, sapphire, Si; silica (96%);
application: hybrid devices

Evaluation: US; wire bond

Schedule

Apparatus: description

Bonding Surface: film thickness; preparation;
topography

Test: pull; visual inspection

DEGRADATION: bond: US; wire: Al; film: Al,
Au/Cr; substrate: alumina, beryllia,
glass, sapphire, Si; silica (96%);
application: hybrid devices

Stress: process; thermal

Part: bond; metallization; wire

Mechanism: intermetallics

Test: pull; resistance

EXPERIMENTAL

- 67P1 Parker, C. D.
INTEGRATED SILICON DEVICE TECHNOLOGY
VOLUME XV RELIABILITY
 Rpt. (March 1966-March 1967), Contract
 No. AF 33(615)-8306, May 1967.
 AD 655082 [see pp. 35-65]
DEGRADATION-bond: TC, US; wire: Al, Au; film:
 Al, Au, Au/Mo; substrate: FeNiCo, Si
Stress: process; thermal
Part: bond
Mechanism: contamination; intermetallics
Failure Rates
TEST
Screening Procedures
FABRICATION-bond: TC, US; wire: Al, Au; film:
 Ag, Ag/Cr, Al, Au, Au/Mo; substrate:
 Si
Evaluation: metal system metallization, wire
Procedure
REVIEW
- 67P2 Pruden, D. H. and D. Schoenthaler
METHODS OF BONDING ELECTRICAL CONDUCTORS TO ELECTRICAL COMPONENTS
 U.S. Patent 3,302,277; Feb. 7, 1967.
TEST-bond: US
Description: bond monitor
PATENT
- 67R1 Riben, A. R. and S. L. Sherman
MICROBONDS FOR HYBRID MICROCIRCUITS
Physics of Failure in Electronics,
 vol. 5, RADC Series in Reliability,
 T. S. Shilliday and J. Vaccaro, eds.,
 1967, pp. 534-556. AD 655397. Summary
 of 66R1, 67R2]
FABRICATION-bond: US; wire: Al; film: Al,
 Au/Cr; substrate: alumina, beryllia,
 silica (96%); application: hybrids
Evaluation: US
Schedule
Variables
Tool: design; wear
Wire: mechanical characteristics
Bonding Surface: film thickness; topography
DEGRADATION-bond: US; wire: Al; film: Al,
 Au/Cr
Stress: process; thermal
Part: bond; metallization
Mechanism: intermetallics
Test: pull; resistance
TEST-bond: US; wire: Al; film: Al, Au/Cr;
 substrate: alumina, beryllia, sapphire;
 silica (96%)
Correlation: pull; resistance
EXPERIMENTAL
- 67R2 Riben, A. R. and S. L. Sherman
MICROBONDS FOR HYBRID MICROCIRCUITS
 Final Rpt. (Feb. 1, 1964-April 30, 1966)
 Contract Number DA 36-039 AMC-03742(E),
 33
- Jan. 1967. AD 647464
FABRICATION-bond: US; wire: Al (pure), Al;
 film: Al, Au/Cr; substrate: alumina,
 sapphire, Si, silica (96%)
Evaluation: metal system
Procedure
Schedule
Apparatus: description
Rigidity: apparatus
Wire: mechanical characteristics
Bonding Surface: film thickness; preparation;
 topography
Test: pull; resistance; thermal shock; visual
 inspection
DEGRADATION-bond: US; wire: Al, Al (pure);
 film: Al, Au/Cr; substrate: alumina,
 sapphire, Si, silica (96%)
Stress: process; test (thermal shock); thermal
Part: wire; bond; metallization
Mechanism: intermetallics
Test: pull; resistance
TEST-bond: US; wire: Al, Al (pure); film: Al,
 Au/Cr; substrate: alumina, sapphire,
 Si, silica (96%)
Evaluation: pull; resistance
Correlation: pull; resistance
EXPERIMENTAL
- 67R3 Reber, R. L.
STEPPED BONDING WEDGE
 U.S. Patent 3,347,442; Oct. 17, 1967.
FABRICATION
Tool: design
PATENT
- 67R4 Rasimenoks, P., T. L. Angelucci, and
 F. W. Kulicke, Jr.
THERMOCOMPRESSION WIRE BONDING APPARATUS
WITH SCISSORS CUT-OFF
 Patent 3,307,763; March 7, 1967.
FABRICATION-bond: TC
Apparatus: design
PATENT
- 67S1 Schnable, G. L. and R. S. Keen
METALLIZATION AND BONDS - A REVIEW OF
FAILURE MECHANISMS
 Proc. 6th Annual Reliability Physics
 Symp., Los Angeles, Calif. pp. 170-192,
 Nov. 1967. [2]
DEGRADATION-bond: TC, US; wire: Al, Au; film:
 Al, Au, Au/Mo
Stress: process; thermal; test (centrifuge)
Part: wire; bond
Mechanism: intermetallics
Failure Rates
FABRICATION-bond: TC, US; wire: Al, Au; film:
 Al, Au, Au/Mo
Evaluation: TC; US
Apparatus: design (US)
Tool: design (TC, US)
REVIEW

67S2 Scarbrough, R. J. D. and J. Auchterlonie
**THE ISOLATION OF A FAILURE MODE IN
SILICON PLANAR TRANSISTORS CAUSED BY
ORGANIC RESIDUES ASSOCIATED WITH
ALUMINUM WIRE**

Microelectronics and Reliability, vol.
6, pp. 319-321, Nov. 1967.

DEGRADATION-wire: Al

Stress: thermal

Part: device

Mechanism: contamination

Test: electrical parameter

ANALYTIC

67S3 Schile, R. D., and G. A. Rosica
**SIMPLE TESTER FOR THE RAPID DETERMINA-
TION OF THE TENSILE STRENGTH OF FINE
FILAMENTS**

Rev. Sci. Instr., vol. 38, pp. 1103-
1104, Aug. 1967.

TEST

Application: pull

DESCRIPTIVE

67S4 Schumacher, D. H.
**MEASURING MICROBOND INTEGRITY WITH AN
INFRARED MICRORADIOMETER**
Soc. for Nondestructive Testing, Inc.,
Fall Conf. ; Cleveland, Ohio, Oct. 1967
(20)

TEST-bond: TC; wire: Au/Cu, film: Au; sub-
strate: ceramic

Description: IR Monitor

Evaluation: IR Monitor

ANALYTIC

67S5 Selikson, B.
**FAILURE MECHANISM INTEGRATED CIRCUIT
INTERCONNECT SYSTEMS**

Proc. 6th Annual Reliability Physics
Symposium, Los Angeles, Calif.
pp. 201-208, Nov. 1967. [2]

DEGRADATION-bond: TC; wire: Al, Au; film:
Ag/Cr; Al, Au/Mo, Au/Mo/Al, Au/Pt/Ti,
Cr/Al

Stress: process; thermal

Part: wire; bond

Mechanism: anneal, intermetallics

Test: pull

FABRICATION-bond: TC; wire: Al, Au; film:
Ag/Cr, Al, Au/Mo, Au/Mo/Al, Au/Pt/Ti,
Cr/Al

Evaluation: metal system

REVIEW

67T1 Tiffany, P.
**VIBRATORY WELDING TIP AND METHOD OF
WELDING**

U.S. Patent 3,357,090; Dec. 12, 1967.

FABRICATION-bond: US; wire: Au

Procedure

Tool: design

PATENT

67V1 van Lancker, M.
METALLURGY OF ALLUMINUM ALLOYS

John Wiley and Sons, Inc., New York
1967.

FABRICATION-wire: Al, Al (pure), Al/Mg

Wire: mechanical characteristics

REVIEW

68A1 Adams, A. H. and J. H. Anderson, Jr.
**MEANS FOR GRIPPING FINE WIRES DURING
MECHANICAL TESTS**

Rev. Sci. Instr., vol. 39, p. 1768,
Nov. 1968.

TEST

Application: pull

DESCRIPTIVE

68A2 Avedissian, M. K. and J. S. Manowczak
**SEQUENTIAL WIRE AND ARTICLE BONDING
METHODS**

U.S. Patent 3,397,451; Aug. 20, 1968.

FABRICATION-bond: TC

Procedure

PATENT

68A3 Anderson, J. H., Jr. and W. P. Cox
**AGING EFFECTS IN AU-AL AND AL-AL
BONDS USED IN MICROELECTRONICS**

Proc. 7th Annual Reliability and
Maintainability Conf., pp. 533-536,
San Francisco, Calif., July 1968.
[7], (21)

DEGRADATION-bond: TC, US; wire: Al, Au; film:
Al

Stress: thermal

Part: wire; bond

Mechanism: anneal, intermetallics

Test: pull; resistance

FABRICATION-bond: TC; wire: Au; film: Al

Bonding Surface: film thickness

EXPERIMENTAL

68B1 Berry, R. W., P. M. Hall, and M. T.
Harris

THIN FILM TECHNOLOGY

Van Nostrand Reinhold Co., Princeton,
New Jersey, 1968, pp. 604-632.

FABRICATION-bond: TC, US

Theory: TC, US

Procedure: TC, US

Schedule: TC

Apparatus: design (US)

Control: temperature (TC, US)

Tool: design (TC)

Wire: size (TC)

.68B1 (cont.)

Test: pull

TEST

Description: centrifuge; IR monitor; metallurgical exam; pull

Evaluation: noise; resistance

REVIEW

68D1 Dummer, G. W. A, and J. M. Robertson, Eds.
ELECTRONIC CONNECTION TECHNIQUES AND EQUIPMENT 1968-1969
Pergamon Press, New York, 1968.

FABRICATION-bond: TC, US

Apparatus: description

DESCRIPTIVE

68D2 Department of Defense
TEST METHODS AND PROCEDURES FOR MICROELECTRONICS
Military Standard 883, May 1, 1968;
Notice 1, May 20, 1968; Notice 2,
Nov. 20, 1969. [1]

TEST-bond: TC, US

Description: air blast; centrifuge; mechanical shock, Mil-Std-883; pull; resistance, shear; temperature cycle; thermal shock; vibration (fatigue, monitored, variable frequency); visual inspection; x-ray

Screening Procedures

STANDARD

68E1 Electronic Design
TEST YOUR IC IQ
Electronic Design, vol. 15, p. 84,
July 18, 1968.

TEST

Precaution: resistance

DESCRIPTIVE

68E2 Electronic Design
TEST YOUR IC IQ
Electronic Design, vol. 2, p. 108,
Jan. 18, 1968.

DEGRADATION

Failure Rates

REVIEW

68F1 Floyd, H. L., Jr.
A TECHNIQUE FOR DETERMINING TRANSISTOR SPALL THRESHOLDS
Sandia Corp. Rpt. No. SC-M-68-186A,
April 1968. [22]

TEST-bond: US, TC

Description: mechanical shock (radiation-induced)

Evaluation: mechanical shock; mechanical shock (radiation-induced)

DEGRADATION-bond: TC, US; wire: Al, Au

Stress: test (mechanical shock (radiation-induced))

Part: bond

Mechanism: spallation

THEORETICAL

68G1 Gaffney, J.
INTERNAL LEAD FATIGUE THROUGH THERMAL EXPANSION IN SEMICONDUCTOR DEVICES
IEEE Trans. Electron Devices, vol. ED-15, p. 617, Aug. 1968.

DEGRADATION-bond: TC; wire: Al, Au; film: Al

Stress: thermal

Part: wire

Mechanism: fatigue

FABRICATION-bond: TC; wire: Al; film: Al

Wire: mechanical characteristics

DESCRIPTIVE

68G2 Gaffney, J., D. Bottaro and C. D. Root
INTERNAL LEAD FATIGUE IN SEMICONDUCTOR DEVICES THROUGH THERMAL EXPANSION
Presentation abstracts 7th Annual Reliability Physics Symp., Washington, D. C., p. 28, Dec. 1968. [2]

DEGRADATION-bond: TC; wire: Al; film: Al

Stress: thermal

Part: wire

Mechanism: fatigue

EXPERIMENTAL

68H1 Harris, D. H.
MEASURING THE ACCURACY OF HUMAN INSPECTION
Mater. Res. Std., vol. 8, pp. 8-12,
Dec. 1968.

TEST

Application: visual inspection

DESCRIPTIVE

68H2 Holmes, P. J., and I. C. Jennings
FAILURE ANALYSIS OF PLANAR TRANSISTORS USED IN THE UK3 SATELLITE PROGRAMME
Microelectronics and Reliability, vol. 7, pp. 37-44, Feb. 1968.

DEGRADATION-bond: TC; wire: Au; film: Al, Au

Stress: process

Part: wire; bond

Mechanism: contamination; intermetallics; thermal mismatch

Failure Rates

DESCRIPTIVE

- 68H3 Hill, W. H., and G. D. Wrench
**RECENT ADVANCES IN PULSE-HEATED WIRE
 BONDING FOR HYBRID MICROELECTRONICS**
 Proc. NEPCON, June 1968. Also Hughes
 Welding Note - Bulletin 109. [4] (23)
 FABRICATION-bond: TC, US; wire: Al, Au; film:
 Al, Au, Cr; substrate: alumina, glass,
 Si; application: hybrid devices
Evaluation: TC; US; temperature control;
tool (TC); wire (TC)
 Apparatus: description (TC)
 Control: temperature (TC)
 Tool: design (TC); wear (TC)
 DESCRIPTIVE
- 68H4 Howard, R. E.
**HOW TO USE IC RELIABILITY SCREENING
 TECHNIQUES**
 Eval. Eng., vol. 7, pp. 22-26, Nov.-
 Dec. 1968.
 TEST
 Evaluation: centrifuge; mechanical shock,
 pull; temperature cycle; thermal shock;
 visual inspection; x-ray
 DESCRIPTIVE
- 68H5 Helda, R. W. and W. E. LaPoint
METHOD OF BONDING FILAMENTARY MATERIAL
 U.S. Patent 3,400,448; Sept. 10, 1968.
 FABRICATION-bond: TC
 Procedure
 Apparatus: design
 PATENT
- 68I1 IEC
**BASIC ENVIRONMENTAL TESTING PROCEDURES
 FOR ELECTRONIC COMPONENTS AND ELECTRON-
 IC EQUIPMENT PART 2: TESTS - TEST GA:
 ACCELERATION, STEADY STATE**
 IEC RECOMMENDATION, PUBLICATION 68-2-7,
 1968. [3]
 TEST
 Description: centrifuge
 STANDARD
- 68J1 Johnson, C. A.
HOT GAS THERMO-COMPRESSION BONDING
 U.S. Patent 3,409,977; Nov. 12, 1968.
 FABRICATION-bond: TC
 Control: temperature
 PATENT
- 68K1 Koshinz, E. F.
**SEMICONDUCTOR: WIRE BONDING AND
 FACE BONDING CONSIDERATIONS AND
 COMPARISONS**
 Proc. SAE Microelectronic Packaging
 Conf., Palo Alto, Calif., pp. 94-100,
 Nov. 1968. (19)
 FABRICATION-bond: TC, US; wire: Al, Au; film:
 Ag/Cr, Al, Au, Au/Cr/Al, Au/Mo/Pt
 Evaluation: TC, US
 Procedure: TC, US
 Variables: TC, US
 REVIEW
- 68L1 Lawhorne, S., and J. N. Ramsey
**SIMPLIFIED X-RAY EXAMINATION OF SOLID
 STATE DEVICES**
 Solid State Technol., vol. 11, pp. 37-
 39, Nov. 1968.
 TEST-wire: Au
 Description: x-ray
 DEGRADATION-wire: Au; application: plastic devices
 Stress: process
 Part: wire
 Test: x-ray
 DESCRIPTIVE
- 68M1 McCormick, J. E.
ON THE RELIABILITY OF MICROCONNECTIONS
 Electron. Packag. Prod., vol. 8, pp.
 187-189, June 1968.
 DEGRADATION-bond: TC, US; wire: Al, Au
 Failure Rates
 FABRICATION-bond: TC, US
 Evaluation: TC; US
 DESCRIPTIVE
- 68M2 Muncheryan, H. M.
**HOW TO USE FAILURE ANALYSIS TO IMPROVE
 SEMICONDUCTOR RELIABILITY**
 EE, vol. 27, pp. 49-54, May 1968.
 DEGRADATION-bond: TC, wire: Au; film: Al, Au
 Stress: process
 Part: bond; metallization; substrate
 Mechanism: contamination; intermetallics
 FABRICATION-bond: TC, US; wire: Al, Au; film:
 Al, Au/Cr, Au/Cu/Ti, Au/Mo, Au/Ni,
 Au/Pt/Ti, Pt/Ti
 Evaluation: metal system
 DESCRIPTIVE
- 68M3 McHale, P. and H. Fenster
**INCREASED YIELDS IN HYBRID THICK FILM
 CIRCUITS BY INDIRECT ACTIVE DEVICE AT-
 TACHMENT**
 IEEE Microelectronics Symp., St. Louis,
 Missouri, pp. D7-1 to D7-6, June 1968.
 [2] (24)
 FABRICATION-bond: TC; wire: Au; film: Al;
 application: hybrid devices
 Evaluation: bond (ball, stitch)
 Control: temperature
 DESCRIPTIVE

68P1 Poston, M. H.
TIME-TEMPERATURE EFFECTS ON WIRE BONDS
IEEE Microelectronics Symp., St. Louis,
Missouri, pp. 1-21, June 1968. [?],
(25)

FABRICATION-bond: TC; wire: Au; film: Al
Variables

Control: force; temperature

DEGRADATION: TC; wire: Au; film: Al

Stress: process; thermal

Part: bond

Mechanism: anneal; grain growth; intermetal-
lics

Test: pull; visual inspection

TEST-bond: TC; wire: Au; film: Al

Description: pull

DESCRIPTIVE

68R1 Rodrigues de Miranda, W. R.
VISUAL INSPECTION OF IC'S BOOSTS
RELIABILITY AT LITTLE COST
Electronics, vol. 41, pp. 104-108,
Aug. 19, 1968.

TEST-bond: TC, US; wire: Al, Au

Description: visual inspection

DESCRIPTIVE

68R2 Ruggiero, E. M.
ALUMINUM BONDING FOR HIGH-POWER IC'S
Microelectronic Packaging, George
Sideris, Ed., McGraw-Hill, New York,
1968, chapt. 7.3, pp. 240-248.

FABRICATION-bond: TC; wire: Al, Au; film: Al,
Au

Evaluation: bond (ball, stitch, wedge), wire
Procedure

Test: centrifuge, mechanical shock, vibration
(variable frequency)

DEGRADATION: bond: TC; wire: Al, Au; film:
Al, Au

Stress: thermal

Mechanism: intermetallics

Failure Rates

DESCRIPTIVE

68S1 Shockley, W. L. and R. W. Weedfall
ULTRASONIC BONDING
Microelectronic Packaging, George
Sideris, Ed., McGraw-Hill, New York,
1968, chapt. 7.2, pp. 232-240.
[see p. 239]

FABRICATION-bond: US; wire: Au, Au/Ga

Wire: care; mechanical characteristics

Bonding Surface: orientation

DESCRIPTIVE

68T1 Takei, W. J. and M. H. Francombe
MEASUREMENT OF DIFFUSION-INDUCED
STRAINS AT METAL BOND INTERFACES
Solid State Electron., vol. 11, pp. 205-
208, Feb. 1968.

DEGRADATION

Stress: thermal

Part: bond

Mechanism: intermetallics

EXPERIMENTAL

68T2 Tanaka, S. and K. Chiba
SEMICONDUCTOR DEVICE UTILIZING AN
A₂AL₃ LAYER AS A DIFFUSION BARRIER
THAT PREVENTS 'PURPLE PLAGUE'

U.S. Patent 3,401,316; Sept. 10, 1968.

FABRICATION-bond: TC, US; wire: Au, Al;

film: Ag/Al, AuAl₂, Al, Cr; substrate:
Si

Evaluation: metal system; metallization

Bonding Surface: metal system, preparation
PATENT

68U1 Uthe, P. M.
THE WIRE

Uthe Technology, Inc. Technical
Newsletter, vol. 1, Sept. 1968.
[summarized in 69U1] (5)

FABRICATION-bond: US; wire: Al, Al/Mg, Au

Evaluation: wire

Schedule

Tool: design

Wire: mechanical characteristics

Test: pull; visual inspection

DEGRADATION-bond: US; wire: Al; film: Al

Stress: process

Part: substrate

DESCRIPTIVE

68U2 Uthe, P. M.
THE SOLID STATE WELD

Uthe Technology, Inc. Technical
Newsletter, vol. 1, May 1968.
[summarized in 69U1] (5)

FABRICATION-bond: US

Theory

DESCRIPTIVE

68U3 Uthe, P. M.
THE FRICTION OF NON-LUBRICATED METALS

Uthe Technology, Inc. Technical
Newsletter, vol. 1, June 1968.
[summarized in 69U1] (5)

FABRICATION-bond: US

Theory

DESCRIPTIVE

68U4 Uthe, P. M.
WELDING

Uthe Technology, Inc. Technical
Newsletter, vol. 1, July 1968.
[summarized in 69U1] (5)

FABRICATION-bond: US

68U4 (cont.)

Theory
Schedule

Control: force; power; time
DESCRIPTIVE

68U5 Uthe, P. M.
A SIMPLE WIRE BONDER
Uthe Technology, Inc. Technical
Newsletter, vol. 1, Aug. 1968.
[summarized in 69U1] (5)

FABRICATION-bond: US
Apparatus: adjustment; design
Rigidity: apparatus; terminal
DESCRIPTIVE

69A1 Ang, C. Y., P. H. Eisenberg and
H. C. Matraw
PHYSICS OF CONTROL OF ELECTRONIC
DEVICES
Proc. 1969 Annual Symp. on Reliability,
Chicago, Ill., pp. 73-85, Jan. 1969.
[see pp. 76, 82] (13)

TEST-bond: TC; wire: Au
Correlation: pull; pull (nondestructive)
DESCRIPTIVE

69A2 Anderson, J. H., Jr. and W. P. Cox
FAILURE MODES IN GOLD-ALUMINUM
THERMOCOMPRESSION BONDS
IEEE Trans. Reliability, vol. R-18,
pp. 206-207, Nov. 1969.
DEGRADATION-bond: TC; wire: Au; film: Al
Stress: thermal
Part: bond; metallization
Mechanism: intermetallics
FABRICATION-bond: TC; wire: Au; film: Al
Bonding Surface: film thickness
EXPERIMENTAL

69A3 Antler, M.
WHAT DO GOLD PLATING SPECS REALLY MEAN?
Products Finishing, vol. 34, pp. 56-
66, Oct. 1969.

FABRICATION-film: Au
Bonding Surface: contamination; film thick-
ness; mechanical characteristics; pre-
paration; topography
DESCRIPTIVE

69B1 Bell, J. L.
UPGRADING OF MICROELECTRONIC TEST
PROCEDURES FOR MILITARY HI-REL
ACHIEVEMENT
Trans. 23rd Annual Technical Conf.,
pp. 767-770, Los Angeles, Calif.,
sponsored by American Society for
Quality Control, Ann Arbor, Mich.,
May 1969.

TEST

Evaluation: temperature cycle; thermal
shock

DESCRIPTIVE

69B2 Binelli, W. D., and R. H. Soltau
DEVELOPMENT OF QUALIFICATION TEST
PROGRAM FOR MICROELECTRONIC DEVICES,
Final Rpt. (Nov. 1, 1968 to July 3,
1969), Contract No. NAS1-8714, Sept.
1969. N70-11544

TEST

Description: centrifuge, mechanical shock;
thermal shock

FABRICATION-bond: US; wire: Al; film: Al, Au
Evaluation: wire bond

Test: centrifuge; mechanical shock; thermal
shock

DESCRIPTIVE

69B3 Budd, J. B.
DIE AND WIRE BONDING CAPABILITIES OF
REPRESENTATIVE THICK-FILM CONDUCTORS
Solid-State Technol. vol. 12,
pp. 59-63, June 1969.

FABRICATION-bond: TC, US; wire: Al, Au;
film: Au/Mo/Mn; thick film: Ag, Ag/Pd,
Au, Au/Pd, Au/Pd/Pt, Au/Pt, Pd/Ag

Evaluation: wire bond; metallization

Variables

Bonding Surface: preparation

Test: pull

DEGRADATION-bond: TC; wire: Au; thick film:
Ag/Pd, Au

Stress: thermal

Test: pull

ANALYTIC

69B4 Browning, G. V.
MONOLITHIC INTEGRATED CIRCUIT FAILURE
MECHANISMS

Nat. Electron. Conf. Seminar, *Design-
ing with Monolithic Integrated Cir-
cuits*, Nat. Electron. Conf., Chicago,
Ill., pp. 1-22, Dec. 1969. (26)

DEGRADATION-bond: TC, wire: Al, Au; film:
Al, Au/Mo

Stress: thermal

Part: bond

Mechanism: intermetallics

Failure Rates

REVIEW

69B5 Bullis, W. M., Ed.
METHODS OF MEASUREMENT FOR SEMICON-
DUCTOR MATERIALS, PROCESS CONTROL,
AND DEVICES
NBS Technical Note 488, Quarterly Rpt.
(Jan. 1 to March 31, 1969), July 1969.
[see pp. 21-25] [30] (29)

69B5 (cont.)

TEST-wire: Al, Au
Application: pull
FABRICATION-bond: US; wire: Al; film: Al
Evaluation: wire (ribbon)
DEGRADATION-bond: US; wire: Al; film: Al
Stress: thermal
Part: wire
Mechanism: anneal
Test: pull
DESCRIPTIVE

69B6 Bullis, W. M., Ed.
METHODS OF MEASUREMENT FOR SEMICONDUCTOR MATERIALS, PROCESS CONTROL, AND DEVICES
NBS Technical Note 495, Quarterly Rpt. (April 1-June 30, 1969), Sept. 1969. [see pp. 24-31] [30] (29)
FABRICATION-bond: US; wire: Al; film: Al
Evaluation: bond (ball); wire (ribbon)
Apparatus: adjustment
Tool: oscillation
TEST-bond: US; wire: Al; film: Al
Description: bond monitor
DESCRIPTIVE

69B7 Bellin, J. L. S., A. E. Brown, A. S. Hamamoto, and G. C. Knollman
PIEZOELECTRIC MONITOR OF MICROELECTRONIC WIRE BONDS
Lockheed Rpt. LMSC B-62-69-9, June 1969. (21)
TEST-bond: US; wire: Al; film: Al
Description: bond monitor
Correlation: bond monitor, pull, visual inspection
EXPERIMENTAL

69B8 Brinton, J.
MIL STD 883 - A REAL TEST CASE
Electronics, vol. 42, pp. 131-136, Aug. 18, 1969.
TEST
Application: Mil-Std-883
DESCRIPTIVE

69C1 Circuits Manufacturing
A PACKAGING TECHNIQUE IS NOT A BONDING METHOD . . . WIRE-LEADS, FLIP-CHIPS, ULTRASONICS, WHAT'S IT ALL ABOUT?
Circuits Mfg., vol. 9, pp. 8-16, Dec. 1969.
FABRICATION
Evaluation: TC; US; wire bond; bond (ball, stitch, wedge)
DESCRIPTIVE

69C2 Cline, J. E., J. M. Morris, and S. Schwartz
SCANNING ELECTRON MIRROR MICROSCOPY AND SCANNING ELECTRON MICROSCOPY OF INTEGRATED CIRCUITS
IEEE Trans. Electron Devices, vol. ED-16, pp. 371-375, April 1969.
FABRICATION
Test: visual inspection (SEM)
DESCRIPTIVE

69D1 Dudderar, T. D.
THE EFFECT OF GRIP STRESSES ON THE OCCURRENCE OF FAILURE IN TENSION TESTS OF WIRE
Mater. Res. Std., vol. 9, pp. 26-30, Oct. 1969.

TEST
Application: pull
THEORETICAL

69D2 Demer, L. J. and L. H. Fentnor
LAMB WAVE TECHNIQUES IN NONDESTRUCTIVE TESTING
Int. J. Nondestructive Testing, vol. 1, pp. 251-283, Oct. 1969.

TEST
Application: US probe
FABRICATION
Wire: mechanical characteristic
Test: US probe
ANALYTIC

69D3 Department of Defense
MILITARY SPECIFICATION MICROCIRCUITS GENERAL SPECIFICATION FOR -
Mil-M-38510, Nov. 20, 1969. [1]
TEST
Application: Mil-Std-883
Screening Procedures
STANDARD

69G1 Gurland, J.
MICROSTRUCTURAL ASPECTS OF THE STRENGTH AND HARDNESS OF CEMENTED TUNGSTEN CARBIDE
Contract No. SD-86, Dec. 1969.
AD 699187

FABRICATION
Tool: design
DESCRIPTIVE

69G2 Grable, R. C. and H. E. Patzer
WIRE BONDING APPARATUS FOR MICROELECTRONIC COMPONENTS
U.S. Patent 3,430,835; March 4, 1969.
FABRICATION-bond: TC; wire: Au
Procedure
PATENT

69H1 Heinen, K. G. and G. B. Larrabee
THE DETERMINATION OF RESIDUAL PHOTORE-
SIST ON SILICON USING RADIOTRACER
IODINE-131
Solid State Technol., vol. 12, pp. 44-
47, April 1969.

FABRICATION

Bonding Surface: contamination

Test: radiotracer

DESCRIPTIVE

69K1 Kashiwabara, M., S. Nakayama and
M. Suzuki
SETTING AND EVALUATION OF ULTRASONIC
BONDING FOR AL WIRE
Rev. Elec. Commun. Lab., vol. 17,
pp. 1014-1021, Sept. 1969.

TEST-bond: US; wire: Al; film: Al

Description: pull

Evaluation: visual inspection

Correlation: pull; visual inspection

FABRICATION-bond: US; wire: Al; film: Al

Procedure

Bonding Surface: film thickness

ANALYSIS

69K2 Krieg, R. D. and W. B. Murfin
STRUCTURAL CONSIDERATIONS IN ELECTRON-
IC MICROCIRCUIT LEAD WIRES
March 1969. PB 183544.

TEST

Application: mechanical shock; temperature
cycle; thermal shock; vibration

THEORETICAL

69K3 Kashiwabara, M. and S. Hattori
FORMATION OF AL-AU INTERMETALLIC
COMPOUNDS AND RESISTANCE INCREASE FOR
ULTRASONIC AL WIRE BONDING
Rev. Elec. Commun. Lab., vol. 17,
pp. 1001-1013, Sept. 1969.

DEGRADATION-bond: US; wire: Al; film: Au;
substrate: FeNiCo

Stress: thermal

Part: bond

Mechanism: intermetallics

Test: metallurgical exam; resistance

FABRICATION: bond: US; wire: Al; film: Au;
substrate: FeNiCo

Procedure

Bonding Surface: film thickness

EXPERIMENTAL

69K4 Knollman, G. C., A. S. Hamamoto, and
J. L. S. Bellin
REPORTS ON ULTRASONIC SCREENING OF
TRANSISTORS AND INTEGRATED CIRCUITS
Lockheed Rpt. LMSC B-62-69-8, June
1969. (21)

TEST-bond: TC, US; wire: Al, Au; film: Al, Au
Description: US stress

DEGRADATION-bond: TC, US; wire: Al, Au; film:
Al, Au

Stress: test (US stress)

Part: bond, wire

Failure Rates

EXPERIMENTAL

69L1 Lauffenburger, H. A. and T. R. Myers
SUMMARY AND INTERPRETATION OF RELIA-
BILITY DATA ON VARIOUS MICROCIRCUIT
BONDING TECHNIQUES

Proc. Holm Seminar on Electrical Con-
tact Phenomena, pp. 61-68, Nov. 1969.
[6]

DEGRADATION-bond: TC, US; wire: Al, Au; film:
Al, Au

Stress: process; thermal

Mechanism: anneal; contamination; intermetal-
lics

Test: pull; shear

Failure Rates

TEST

Screening Procedures

REVIEW

69L2 Laub, J. L. and M. N. Mansour
WIRE CLAMP
U.S. Patent 3,430,834; March 4, 1969.

FABRICATION-bond: US

Apparatus: design

PATENT

6901 O'Connell, E. P.
AN INTRODUCTION TO MIL-STD-883 TEST
METHODS AND PROCEDURES FOR MICROELEC-
TRONICS
Proc. 8th Reliability and Maintain-
ability Conf., Denver, Colorado, pp.
530-542, July 1969. [10] (27)

TEST

Description: centrifuge; Mil-Std-883; pull;
temperature cycle; visual inspection

Evaluation: centrifuge; visual inspection

DEGRADATION-bond: TC, US; wire: Al, Au;
film: Al, Au

Stress: thermal

Mechanism: anneal, intermetallics

Test: pull

Failure Rates

REVIEW

6902 Ono, K., M. Nishihata and S. Kobayashi
FINE ALUMINUM TRANSISTOR LEAD WIRES
Rev. Elec. Commun. Lab., vol. 17,
pp. 974-988, Sept. 1969.
FABRICATION-bond: TC, US; wire: Al, Al (pure);
film: Al, Au

6902 (cont.)

Wire: electrical characteristics; fabrication; mechanical characteristics; topography

Test: pull

DEGRADATION-bond: TC, US; wire: Al; film: Al, Au

Stress: thermal

Part: wire

Mechanism: anneal; grain growth

Test: pull

EXPERIMENTAL

69P1 Plough, C., D. Davis, and H. Lawler
HIGH RELIABILITY ALUMINUM WIRE BONDING
Proc. Electronic Components Conf.,
Washington, D. C., pp. 157-165, April-May 1969. [2] (28)

FABRICATION-bond: US; wire: Al, Au; film: Al, Au

Theory

Schedule

Variables

Apparatus: adjustment

Tool: design

Rigidity: apparatus; terminal

Bonding Surface: contamination; mechanical characteristics; topography

Test: pull, visual inspection

TEST-bond: US; wire: Al; film: Al, Au

Evaluation: air blast; thermal shock; visual inspection

Correlation: mechanical shock (radiation-induced); pull; visual inspection

DEGRADATION-bond: US; wire: Al, Al/Mg

Stress: thermal

Part: wire; device

Mechanism: anneal, contamination

Test: electrical parameters; pull

DESCRIPTIVE

69R1 Ruth, S. B.
TORTURE TESTS IMPROVE EQUIPMENT RELIABILITY

The Electronic Engineer, vol. 28,
pp. 80-87, June 1969.

TEST

Description: centrifuge; mechanical shock; thermal shock; vibration

DESCRIPTIVE

69S1 Slemmons, J. W.
THE MICROWORLD OF JOINING TECHNOLOGY
American Welding Society 50th Annual
Meeting and Welding Exposition; Philadelphia, Pa., April-May, 1969. [8] (13)

FABRICATION-bond: TC, US; wire: Al, Au, film: Al, Au

Theory: TC, US

Evaluation: US

Procedure: TC, US

Test: pull

TEST-bond: TC; wire: Au

Description: pull; pull (nondestructive); visual inspection (SEM); x-ray

DEGRADATION: bond: TC; wire: Au; film: Al

Stress: thermal

Part: bond

Mechanism: intermetallics

Test: visual inspection (SEM)

REVIEW

69S2 Schnable, G. L. and R. S. Keen
ALUMINUM METALLIZATION ADVANTAGES AND LIMITATIONS FOR INTEGRATED CIRCUIT APPLICATIONS

Proc. IEEE, vol. 57, pp. 1570-1580,
Sept. 1969.

FABRICATION-bond: TC, US; wire: Al, Au; film: Al, Au/Cr, Au/Mo

Evaluation: metallization

REVIEW

69S3 Selikson, B.
VOID FORMATION FAILURE MECHANISMS IN INTEGRATED CIRCUITS

Proc. IEEE, vol. 57, pp. 1594-1598,
Sept. 1969.

DEGRADATION-wire: Al, Au; film: Al, Au

Stress: thermal

Part: bond

Mechanism: intermetallics

FABRICATION-wire: Au; film: Au/Ag/Cr, Au/Mo, Au/Ti/Al, Au/Pt/Ti/Pt, Cr/Al

Evaluation: metal system

REVIEW

69S4 Shurtleff, W. O.
RELIABILITY HANDBOOK FOR SILICON MONOLITHIC MICROCIRCUITS VOLUME 2 - FAILURE MECHANISMS OF MONOLITHIC MICROCIRCUITS
Contract NAS 8-20639, April 1969.
N69-23226. [see pp. 2-IV-2 to 2-IV-6]

TEST

Description: centrifuge; mechanical shock; temperature cycle; thermal shock; vibration (variable frequency, fatigue)

Evaluation: vibration (variable frequency); visual inspection

DESCRIPTIVE

69S5 Speer, R. D.
CHIP BONDING: PROMISES AND PERILS
Electronic Design, vol. 17, pp. 61-79,
Oct. 25, 1969.

FABRICATION-bond: TC, US

Evaluation: wire bond

REVIEW

69T1 Tamburrine, A. L. and V. C. Kapfer
FAILURE MECHANISMS IN PLASTIC ENCAP-
SULATED MICROCIRCUITS
Contract No. AF-5519, May 1969.
AD 689224

DEGRADATION-bond: TC; wire: Au; film: Ag, Al,
Au, Ni; application: plastic devices
Stress: moisture; test (thermal shock);
thermal
Part: wire; bond
Mechanism: corrosion; thermal mismatch
ANALYTIC

69T2 Tarowsky, N.
HOW TO ASSEMBLE HYBRID MICROWAVE IC's
Microwaves, vol. 8, pp. 52-62, Aug.
1969.
FABRICATION-bond: TC, US; application: hy-
brids
Evaluation: TC; US
DESCRIPTIVE

69U1 Uthe, P. M.
VARIABLES AFFECTING WELD QUALITY IN
ULTRASONIC ALUMINUM WIRE BONDING
Solid State Technol., vol. 12, pp. 72-
76, Aug. 1969.

FABRICATION-bond: US; wire: Al, Al/Mg, Au;
film: Al, Au

Theory

Evaluation: wire

Schedule

Apparatus: adjustment; description; design

Tool: adjustment

Rigidity: apparatus; package

Wire: mechanical characteristics

Test: pull, visual inspection

Trouble Shooting

DEGRADATION-bond: US; wire: Al, substrate: Si

Stress: process

Part: substrate

DESCRIPTIVE

69U2 Uthe, P. M., Jr., L. G. Wright, and
R. E. Greenan
ULTRASONIC FREQUENCY POWER SUPPLY
U.S. Patent 3,445,750; May 20, 1969.

FABRICATION-bond: US

Apparatus: design

PATENT

70A1 Adams, M. A.
AN INVESTIGATION OF THE STRENGTH OF
ALUMINUM WIRE USED IN INTEGRATED CIR-
CUITS
NASA Tech. Brief 70-10275, Aug.
1970. [9]

TEST-bond: TC, US; wire: Al, Au; film: Al,
Au

Description: pull

DEGRADATION-bond: TC, US; wire: Al, Au; film:
Al, Au

Stress: test (pull); thermal

Part: wire

Mechanism: anneal; grain growth

Test: visual inspection (SEM)

DESCRIPTIVE

70A2 Anderson, Jr., J. H., T. G. Maple, and
W. P. Cox
AGING EFFECTS IN GOLD THERMOCOMPRESSION
BONDS TO COMPLEX METALLIZATIONS
IEEE Trans. Reliability, vol. R-19,
pp. 32-34, Feb. 1970.

DEGRADATION-bond: TC; wire: Au; film: Al,
Au/Mo/Al, Au/Ti/Al

Stress: thermal

Part: bond

Mechanism: intermetallics

Test: pull; resistance

FABRICATION-bond: TC; wire: Au; film: Al,
Au/Mo/Al; Au/Ti/Al

Evaluation: metal system

Bonding Surface: preparation

EXPERIMENTAL

70A3 ASTM
STANDARD SPECIFICATION FOR GOLD WIRE
FOR SEMICONDUCTOR LEAD-BONDING
(ASTM DESIGNATION: F72-69)
1970 Annual Book of ASTM Standards,
part 8, 1970. [11]

FABRICATION-wire: Au

Wire: care; contamination; mechanical char-
acteristics; size

STANDARD

70A4 ASTM
STANDARD METHODS OF TESTING FINE ROUND
AND FLAT WIRE FOR ELECTRON DEVICE AND
LAMPS (ASTM DESIGNATION: F219-67)
1970 Annual Book of ASTM Standards,
part 8, 1970. [11]

FABRICATION

Wire: mechanical characteristics, size

STANDARD

70A5 ASTM
STANDARD METHOD FOR MEASURING DIAMETER
OF FINE WIRE BY WEIGHING (ASTM DESIG-
NATION: F205-63)
1970 Annual Book of ASTM Standards,
part 8, 1970. [11]

FABRICATION

Wire: size

STANDARD

70A6 ASTM
STANDARD METHODS OF TENSION TESTING
OF METALLIC MATERIALS (ASTM DESIGNATION:
E8-69)
1970 Annual Book of ASTM Standards,
part 31, 1970. [11]

Test

Application: pull

STANDARD

70A7 ASTM
STANDARD METHOD OF TEST FOR RESISTIVITY
OF ELECTRICAL CONDUCTOR MATERIALS (ASTM
DESIGNATION: B193-65)
1970 Annual Book of ASTM Standards,
part 8, 1970. [11]

FABRICATION

Wire: electrical characteristics

STANDARD

70B1 Bevington, J. R., J. P. Cook, and
D. R. Little
PLASTIC IC RELIABILITY EVALUATION AND
ANALYSIS
8th Annual Proc. Reliability Physics,
IEEE Catalog No. 70C59-PHY, pp. 73-80,
1970. [abbreviated version of 71B3] [2]

TEST-bond: TC; wire: Au; film: Au, Ag; appli-
cation: plastic devices

Evaluation: thermal shock

DEGRADATION-bond: TC; wire: Au; film: Au;
application: plastic devices

Stress: test (thermal shock)

Part: bond; wire

Mechanism: thermal mismatch

EXPERIMENTAL

70B2 Bullis, W. M., Ed.
METHODS OF MEASUREMENT FOR SEMICONDUCTOR
MATERIALS, PROCESS CONTROL, AND DEVICES
NBS Technical Note 520, Quarterly Rpt.
(July 1-Sept. 30, 1969), March 1970.
[see pp. 32-43] [30] (29)

FABRICATION-bond: US; wire: Al; film: Al

Apparatus: design

Tool: adjustment; design; oscillation

Rigidity: apparatus

Test: interferometry

DEGRADATION-bond: US; wire: Al; film: Al

Stress: thermal

Part: wire

Mechanism: anneal

Test: pull

TEST-bond: US; wire: Al; film: Al

Description: resistance

EXPERIMENTAL

70B3 Bullis, W. M., Ed.
METHODS OF MEASUREMENT FOR SEMICONDUCTOR
MATERIALS, PROCESS CONTROL, AND DEVICES

NBS Technical Note 527, Quarterly Rpt.
(Oct. 1-Dec. 31, 1969), May 1970.

[see pp. 31-47] [30] (29)

FABRICATION-bond: US; wire: Al; film: Al
Theory

Apparatus: adjustment

Tool: adjustment; oscillation

Rigidity: apparatus

Wire: contamination; mechanical character-
istics

Bonding Surface: preparation

Test: pull

EXPERIMENTAL

70B4 Brauer, J. B., V. C. Kapfer, and
A. L. Tamburrino
CAN PLASTIC ENCAPSULATED MICROCIRCUITS
PROVIDE RELIABILITY WITH ECONOMY?
8th Annual Proc. Reliability Physics,
IEEE Catalog No. 70C59-PHY, pp. 61-
72, 1970. [2] (27)

DEGRADATION-application: plastic devices
Stress: moisture, process, test (temperature
cycle)

Part: metallization, wire

Mechanism: corrosion; fatigue; thermal mis-
match

Test: resistance, x-ray

Failure Rates: general

DESCRIPTIVE

70B5 Bradfield, G.
ULTRASONIC TRANSDUCERS - 1. INTRODUC-
TION TO ULTRASONIC TRANSDUCERS,
PART A
Ultrasonics, vol. 8, pp. 112-123,
April 1970.

FABRICATION-bond: US

Apparatus: design

REVIEW

70B6 Bradfield, G.
ULTRASONIC TRANSDUCERS - 1. INTRODUC-
TION TO ULTRASONIC TRANSDUCERS,
PART B
Ultrasonics, vol. 8, pp. 177-189,
July 1970.

FABRICATION-bond: US

Apparatus: design

REVIEW

70B7 Bullis, W. M. and A. J. Baroody, Jr.,
Eds.
METHODS OF MEASUREMENT FOR SEMICONDUCTOR
MATERIALS, PROCESS CONTROL, AND
DEVICES
NBS Technical Note 555, Quarterly Rpt.
(Jan. 1 to March 31, 1970), Sept. 1970.
[see pp. 27-36] [30] (29)

70B7 (cont.)

TEST

Description: centrifuge; pull; US stress

Application: bond monitor

FABRICATION-bond: US

Tool: design

Rigidity: apparatus

Test: pull; visual inspection (SEM)

DESCRIPTIVE

70B8 Bullis, W. M. and A. J. Baroody, Jr.,
Eds.

**METHODS OF MEASUREMENT FOR SEMICONDUCTOR
MATERIALS, PROCESS CONTROL, AND DEVICES**

NBS Technical Note 560, Quarterly Rpt.

(April 1 to June 30, 1970), Nov. 1970.

[see pp. 29-38] [30] (29)

FABRICATION-bond: US

Theory: US

Schedule

Wire: mechanical characteristics

Rigidity: apparatus

Test: pull; visual inspection (SEM)

TEST

Evaluation: pull

Application: pull

DEGRADATION

Stress: process; test (pull)

Part: bond

Test: visual inspection (SEM)

DESCRIPTIVE

70C1 Cox, W. P., E. E. Anderson, and
J. H. Anderson, Jr.

**ULTRASONIC ALUMINUM WIRE BONDING FOR
MICROELECTRONIC APPLICATIONS**

Proc. 1970 Annual Symp. on Reliability,

Los Angeles, Calif., vol. 3, pp. 228-

236, Feb. 1970. (31)

FABRICATION-bond: US; wire: Al; film: Al

Evaluation: wire

Control: force, power, time

Test: pull; resistance; visual inspection

DEGRADATION-bond: US; wire: Al; film: Al

Stress: process, thermal

Part: wire; substrate

Mechanism: anneal

Test: pull, resistance; visual inspection

EXPERIMENTAL

70C2 Curran, L.

PLASTIC IC'S GET FOOT IN MILITARY DOOR

Electronics, vol. 43, pp. 127-130,

May 11, 1970.

TEST-application: plastic devices

Description: Mil-Std-883

DESCRIPTIVE

70D1 Devaney, J. R.

**APPLICATION OF SCANNING ELECTRON
MICROSCOPY TO INTEGRATED CIRCUIT
FAILURE**

Solid State Technol., vol. 13, pp. 73-
77, March 1970.

DEGRADATION-bond: TC; wire: Au; film: Al

Part: bond

Mechanism: contamination

Test: visual inspection (SEM)

DESCRIPTIVE

70D2 Davis, D.

**FACTORS IN HIGH RELIABILITY WIRE
BONDING**

8th Annual Proc. Reliability Physics,

IEEE Catalog No. 70C59-PHY, pp. 170-

176, 1970. [similar to 69P1] [2] (28)

FABRICATION-bond: US; wire: Al; film: Al, Au

Schedule

Variables

Apparatus: adjustment, design

Tool: adjustment; design; oscillation

Rigidity: apparatus, terminal, package

Bonding Surface: contamination; thickness;
topography

Test: pull; visual inspection

TEST-bond: US; wire: Al; film: Al, Au

Correlation: pull; mechanical shock (radia-
tion induced); visual inspection

REVIEW

70D3 Department of Defense

**MILITARY STANDARD - TEST METHODS FOR
SEMICONDUCTOR DEVICES**

Military Standard 750B, Feb. 27, 1970.

[1]

TEST

Description: centrifuge; mechanical shock;
thermal shock; vibration (fatigue,
monitored, variable frequency)

STANDARD

70D4 Dicken, H. K.

**SURVEYING CHIP INTERCONNECTION TECH-
NIQUES**

Electron. Packag. Prod., vol. 10,
sect. 1, pp. 34-45, Oct. 1970.

FABRICATION-bond: TC, US; wire: Al, Au;

film: Al, Au

Evaluation: TC, US, wire bond

REVIEW

70H1 Hnatek, E. R.

PLASTIC IC'S ENTICE MILITARY

EDN, vol. 15, pp. 43-47, Nov. 15, 1970.

DEGRADATION-application: plastic devices

Stress: test (temperature cycle, thermal
shock)

Failure Rates

DESCRIPTIVE

70H2 Haberer, J. R.
**STRESS INDUCED INTERMITTENT FAILURES
IN ENCAPSULATED MICROCIRCUITS**
Report No. RADC-TR-70-213, pp. 1-49,
Oct. 1970. AD 715984 [see also 71H2]
[1] (27)

TEST-bond: TC; wire: Au; application: plastic
devices

Description: resistance; temperature cycle
Evaluation: resistance; temperature cycle
DEGRADATION-bond: TC; wire: Au; application:
plastic devices
Stress: moisture, test (temperature cycle)
Part: bond; metallization; wire
Mechanism: corrosion; thermal mismatch
EXPERIMENTAL

70M1 Miller, L. F.
A CRITIQUE OF CHIP-JOINING TECHNIQUES
Solid State Technol., vol. 13, pp. 50-
62, April 1970.

FABRICATION
Evaluation: wire bond
REVIEW

70M2 Mann-Nachbar, P., and W. Nachbar
**THERMAL SHOCK FOLLOWING RAPID UNIFORM
HEATING OF SPHERES AND LONG CYLINDRICAL
RODS**

Rpt. (April-August, 1968), Contract No.
F04701-69-C-0066, Feb. 1970. AD 702170

TEST
Application: mechanical shock (radiation-
induced)
THEORETICAL

70P1 Pankratz, J. M. and D. R. Collins
**A COMPARISON OF 1% MG-AL AND 1% SI-AL
WIRE INTERCONNECTS**
8th Annual Proc. Reliability Physics,
IEEE Catalog No. 70C59-PHY, pp. 163-
169, 1970. [also published in IEEE
Trans. Reliability, vol. R-19, pp. 89-
94, Aug. 1970] [2] (32)

FABRICATION-bond: US; wire: Al, Al/Mg
Evaluation: wire
Bonding Surface: topography
DEGRADATION-bond: US; wire: Al/Mg
Stress: thermal
Part: device
Mechanism: contamination
EXPERIMENTAL

70P2 Philofsky, E.
**INTERMETALLIC FORMATION IN GOLD-ALUMINUM
SYSTEMS**
Solid State Electron., vol. 13, pp.
1391-1399, Oct. 1970. [also 8th Annual
Proc. Reliability Physics Symp., pp.
177-185, 1970]

DEGRADATION-wire: Al, Al (pure), Au
Stress: thermal
Mechanism: intermetallics
Test: metallurgical exam; pull
TEST
Application: temperature cycle; thermal shock
EXPERIMENTAL

70R1 Rossiter, T. J.
AMBIENT EFFECTS ON GOLD-ALUMINUM BONDS
8th Annual Proc. Reliability Physics,
IEEE Catalog No. 70C59-PHY, pp. 186-
190, 1970. [2] (27)

DEGRADATION-bond: TC; wire: Au; film: Al
Stress: thermal
Part: bond
Mechanism: intermetallics
Test: pull; resistance
EXPERIMENTAL

70S1 Spectrum
**HIGH-PRESSURE PROCESS MAKES WIRE BY
SQUEEZING**

Spectrum, vol. 7, pp. 21, Aug. 1970.

FABRICATION
Wire: fabrication
DESCRIPTIVE

70S2 Straub, R. J.
**RELIABILITY OF HYBRID MICROCIRCUITS IN
USE TODAY**

Proc. Electronic Components Conf.,
May 1970. [2] (33)

TEST-application: hybrids
Evaluation: Mil-Std 883
Screening Procedures
DEGRADATION-bond: TC; application: hybrids
Failure Rates
DESCRIPTIVE

70V1 Villella, F. and M. F. Nowakowski
**INVESTIGATION OF FATIGUE PROBLEM IN
1-MIL DIAMETER THERMOCOMPRESSION AND
ULTRASONIC BONDING OF ALUMINUM WIRE**
NASA Technical Memorandum, NASA
TM X-64566, pp. 1-45, Nov. 30, 1970.
N71-16494

DEGRADATION-bond: TC, US; wire: Al, Au;
film: Al
Stress: thermal
Part: wire
Mechanism: fatigue
Test: pull; visual inspection (SEM)
Failure Rates
TEST
Application: temperature cycle
EXPERIMENTAL

- 70W1 Wilson, A. D., B. D. Martin, and D. H. Strobe
HOLOGRAPHIC INTERFEROMETRY APPLIED TO MOTION STUDIES OF ULTRASONIC BONDERS
IEEE Ultrasonics Symp., San Francisco, Calif., Oct. 21-23, 1970. [2] (34)
FABRICATION-bond: US
Apparatus: design
Tool: oscillation
Test: interferometry
DESCRIPTIVE
- 70W2 Wood, W. A.
FATIGUE CRACK INITIATION AS VIEWED BY SCANNING ELECTRON MICROSCOPY
Contract N-00014-67-A-0214-0011, Rpt., Jan. 1970. AD 704789
DEGRADATION
Stress: mechanical
Part: wire
Mechanism: fatigue
ANALYTIC
- 71B1 Bullis, W. M., Ed.
METHODS OF MEASUREMENT FOR SEMICONDUCTOR MATERIALS, PROCESS CONTROL, AND DEVICES
NBS Technical Note 571, Quarterly Rpt. (July 1-Sept. 30, 1970), April 1971. [see pp. 23-32] [30] (29)
FABRICATION-bond: US; wire: Al; film: Al
Tool: design; oscillation
Rigidity: apparatus
TEST-bond: US; wire: Al; film: Al
Evaluation: pull
DEGRADATION-bond: US; wire: Al; film: Al
Stress: process
Part: wire
EXPERIMENTAL
- 71B2 Boylan, J. R.
THERMOCOMPRESSION BONDING
IEEE Intern. Conv. Digest, New York, Session 7C1, pp. 598-599, March 1971. [2]
FABRICATION-bond: TC, US; wire: Al, Au
Evaluation: TC, US; wire bond; temperature control
Procedure: TC
Tool: design (TC)
Rigidity: terminal
REVIEW
- 71B3 Bevington, J. R., J. P. Cook, D. R. Little, and L. V. Ingle
RELIABILITY EVALUATION OF PLASTIC INTEGRATED CIRCUITS
Rpt. (Jan. 9, 1969 to Sept. 9, 1970)
Contract No. F30602-69-C-0154, pp. 1-154, Jan. 1971. AD 722043 [70B1 is abbreviated version] [1]
TEST-bond: TC; wire: Au; film: Ag, Au;
application: plastic devices
Evaluation: thermal shock
DEGRADATION-bond: TC; wire: Au; film: Au;
application: plastic devices
Stress: test (thermal shock)
Part: bond; wire
Mechanism: thermal mismatch
EXPERIMENTAL
- 71B4 Bullis, W. M., Ed.
METHODS OF MEASUREMENT FOR SEMICONDUCTOR MATERIALS, PROCESS CONTROL, AND DEVICES
Quarterly Rpt. (Oct. 1-Dec. 31, 1970)
NBS Technical Note 592. [see pp. 34-45], [30] (29)
TEST-bond: US; wire: Al; film: Al
Description: bond monitor
Application: pull
FABRICATION-bond: US
Apparatus: adjustment (US); design (US)
Rigidity: apparatus
Wire: mechanical characteristics
DEGRADATION: bond: US; wire: Al; film: Al
Stress: process
Part: bond; wire
Mechanism: anneal
Test: pull
DESCRIPTIVE
- 71D1 Dushkes, S. Z.
A DESIGN OF ULTRASONIC BONDING TIPS
IBM J. Res. Develop., vol. 15, pp. 230-235, May 1971.
FABRICATION-bond: US; wire: Au/CuBeO; film: Au/Cu; substrate: epoxy
Tool: design; oscillation
Test: pull
EXPERIMENTAL
- 71G1 Glass, R. A., T. G. Maple, and R. D. Wales
INTERCONNECTION PROBLEM AREAS IN MICROCIRCUITS
IEEE Intern. Conv. Digest, New York, Session 5B, pp. 248-249, March 1971. [2]
FABRICATION-bond: US; wire: Al; film: Al, Au; substrate: Fe/Ni/Co
Tool: design
Bonding Surface: contamination; film thickness; metal system; preparation
Test: pull, visual inspection
DEGRADATION-bond: US
Stress: process
Part: wire
TEST-bond: US; wire: Al; film: Al
Correlation: pull, visual inspection
EXPERIMENTAL

71G2 Goldfarb, S.
WIRE BONDS ON THICK FILM CONDUCTORS
Proc. Electronic Components Conf.,
Washington, D. C., pp. 295-302, May
1971. [2] (36)

DEGRADATION-bond: US; wire: Al, Au; thick
film: Au

Stress: thermal

Part: bond; wire

Test: pull; resistance

EXPERIMENTAL

71H1 Harman, G. G. and H. K. Kessler
APPLICATION OF CAPACITOR MICROPHONES
AND MAGNETIC PICKUPS TO TUNING AND
TROUBLE SHOOTING OF MICROELECTRONIC
ULTRASONIC BONDING EQUIPMENT
NBS Tech. Note 573, pp. 1-22, May 1971.
[30] (29)

FABRICATION-bond: US

Apparatus: adjustment

Tool: adjustment, oscillation

Trouble Shooting

DESCRIPTIVE

71H2 Haberer, J. R.
TECHNIQUES FOR DETECTING STRESS INDUCED
INTERMITTENT FAILURES IN ENCAPSULATED
DEVICES
IEEE Intern. Conv. Digest, New York,
Session 7CJ, pp. 612-613, March 1971.
[see also 70H2]

TEST-bond: TC; wire: Au; application:
plastic devices

Description: resistance; temperature cycle

Evaluation: resistance; temperature cycle

DEGRADATION-bond: TC; wire: Au; application:
plastic devices

Stress: moisture, test (temperature cycle)

Part: bond; metallization; wire

Mechanism: corrosion; thermal mismatch

EXPERIMENTAL

71H3 Hart, R. R.
A WIRE EXTENSOMETER FOR DETERMINING THE
MECHANICAL PROPERTIES OF FINE WIRES
Mater. Res. Std., vol. 11, pp. 26-28,
April 1971.

FABRICATION

Wire: mechanical characteristics

EXPERIMENTAL

71J1 Johannesen, F.
ULTRASONIC ALUMINUM WIRE BONDING
IEEE Intern. Conv. Digest, Session 7CI,
pp. 600-601, March 1971.

FABRICATION-bond: US; wire: Al; film: Al, Au;
substrate: Fe/Ni/Co

Variables

Apparatus: design
Tool: design, wear
Rigidity: apparatus, package
Bonding Surface: topography
REVIEW

71K1 Kalvelage, B. F.
A PNEUMATIC SHOCK TESTER FOR ELECTRON
DEVICES

Solid State Technol., vol. 14, pp. 57-
59, March 1971.

TEST

Description: mechanical shock

DESCRIPTIVE

71K2 King, C. M.
DYNAMIC SIMULATION OF AN ULTRASONIC
WIRE BONDING TOOL
Raytheon Report ER71-4135, Contracts
N0003070-C0055 and N0003071-C0061,
Jan. 25, 1971. (35)

TEST

Application: bond monitor

THEORETICAL

71L1 Leyshon, W. E., and R. E. Warr
AN OVERVIEW OF HYBRID INTEGRATED CIR-
CUIT RELIABILITY PROBLEMS AND SOLUTIONS
IEEE Intern. Conv. Digest, New York,
Session 7CJ, pp. 606-607, March 1971.

DEGRADATION-application: hybrid devices

Stress: moisture; test (temperature cycle)

Part: metallization, wire

Mechanism: contamination; corrosion; fatigue;
intermetallics

Test: resistance

REVIEW

71M1 Matcovich, T. J.
INTERCONNECTIONS IN HYBRID CIRCUITS
IEEE Intern. Conv. Digest, New York,
Session 5B, pp. 240-241, March 1971.

FABRICATION-bond: TC, US

Evaluation: wire bond

REVIEW

71N1 NASA
LINE CERTIFICATION REQUIREMENTS FOR
MICROCIRCUITS
NHB 5300.4(3C), May 1971. [30]

TEST

Description: Mil-Std-883; pull; resistance;
visual inspection; visual inspection (SEM)

Application: Mil-Std-883

Screening Procedures

STANDARD

71N2 NASA
TEST STANDARDS FOR MICROCIRCUITS
NHB 5300.4(3D), May 1971. [30]

TEST

Description: mechanical shock; pull; resistance

STANDARD

71P1 Philofsky, E.
DESIGN LIMITS WHEN USING GOLD-ALUMINUM BONDS

9th Annual Proc. Reliability Physics
Symp., Las Vegas, IEEE Catalog No.
71-C-9-PHY, 1971. [2] (37)

FABRICATION-bond: TC, US; wire: Al, Au; film: Al, Au

Bonding Surface: film thickness

DEGRADATION-bond: TC, US; wire: Al, Au;
film: Al, Au

Stress: test (temperature cycle); thermal

Part: bond; wire

Mechanism: fatigue; intermetallics

ANALYTIC

71P2 Philofsky, E., R. Bowman, and W. Miller
ALUMINUM ULTRASONIC JOINING IN SPIDER AND WIRE CONNECTIONS

Proc. Electronic Components Conf.,
Washington, D. C., pp. 289-294, May
1971. [2] (37)

FABRICATION-bond: US; wire: Al; film: Al

Theory: US

Evaluation: US

Bonding Surface: topography

REVIEW

71R1 Ravi, K. V. and E. Philofsky
THE STRUCTURE AND MECHANICAL PROPERTIES
OF FINE DIAMETER ALUMINUM - 1 PCT SI
WIRE

Metallurgical Transactions, vol. 2,
pp. 711-717, March 1971.

FABRICATION-bond: TC, US; wire: Al

Evaluation: wire

Wire: mechanical characteristics

DEGRADATION-bond: TC, US; wire: Al

Stress: thermal

Part: wire

Mechanism: anneal; fatigue; grain growth

Test: pull

EXPERIMENTAL

71S1 Straub, R. J. and J. P. Farrell
THE EFFECTIVITY OF SCREENING HYBRID
MICROCIRCUITS PER MIL-STD-883

Proc. Electronics Components Conf.,
Washington, D. C., pp. 17-26, May 1971.
[2] (38)

TEST-bond: TC; wire: Au; film: Al, Au;
application: hybrid devices

Screening Procedures

DEGRADATION-bond: TC; wire: Au; film: Al, Au
application: hybrid devices

Stress: test (centrifuge, mechanical shock,
temperature cycle, thermal shock)

Part: bond, wire

EXPERIMENTAL

Appendix A. Organization of Bibliography

Each entry has been given an *identification code* which consists of a sequence of two digits, a letter, and another digit. The first two digits indicate the year of publication and the letter is the initial of the first author's surname. The last digit is used to distinguish those papers which would otherwise have the same code. No rule was used in the assignment of the last digit. The papers in the bibliography are arranged according to their codes. The codes are grouped first by year, then in alphabetical order by letter, and then in numerical order by the last digit.

Key words (or phrases) are listed beneath each reference in the bibliography to indicate the contents and approach of the paper. Three levels of key words are used to indicate the subject matter of the entries at three levels of detail. These levels and the key words assignments are discussed in Appendix D. A *Key Word Index* is provided and presented in two parts. The first part lists the key words in alphabetical order with the page number where the same key word may be found in the second part of the Index. This second part lists the key words by subject area. With each key word is a tabulation of literature citations (using their identification codes). In both parts

of the Index, key words that may require additional definition are followed by clarifying notes, in brackets, except for those for the test methods. Brief descriptions of the test methods may be found in *Table 4*. Here, key words for the test methods are listed in alphabetical order with a brief description for each. The test methods listed are not necessarily restricted to testing wire bonds. However, the descriptive phrases are directed to the particular function described in the papers compiled.

Reading priority is suggested by giving prominence to those papers that are of such scope or relative importance in a particular area that they should be seen first. These papers are so indicated by underlining the identification code for the paper listed under the appropriate key word in the Key Word Index. They are also indicated by underlining the code of the citation and the appropriate key word(s) in the bibliography.

Some citations are followed by notes which refer to additional information intended to assist in obtaining the referenced work. This and other information related to *availability* is included in Appendix C.

A complete *Author Index* is also provided.

Appendix B. Sources for Bibliography and Abbreviations

The *sources* of the bibliography are listed in *Table 1*. Emphasis was placed on searching the report and journal literature from 1965 to 1970. Citations to much of the important earlier work were found in the articles published during this period. Another source of papers was a number of restricted bibliographies, containing references to unrestricted literature, and personal files.

The journal or conference *abbreviations* generally follow those of the *Chemical Abstracts*. In

order to minimize any possible confusion, those journals abbreviated are listed in alphabetical order by their abbreviations in *Table 2*. Additional abbreviations are included which are used in citations to some conference meetings. Another purpose of this Table is to indicate those journals which have been scanned completely at least over the period from 1965 to 1970, inclusive. They are indicated by an asterisk in the left-hand margin.

Appendix C. Availability

Some entries in the bibliography have availability notices after the citation to assist in procurement.

The citations to reports available from the *National Technical Information Service (NTIS)*, Sills Building, 5285 Port Royal Road, Springfield, Virginia 22151, are followed by a number preceded by the letters AD or PB, or the letter N. This is the NTIS Accession number which should be used when ordering.

A number of other entries, generally to conference papers, have the citation followed by a number either in brackets or parentheses. The number refers to an address listed in *Table 3*. If the number is in brackets the address listed is one to which an order may be placed for the paper or the conference proceedings. If the number is in parentheses the address is that of the first author's place of work at the time the paper was published.

TABLE 1. SOURCES FOR BIBLIOGRAPHY

1. Bibliographic search by the Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314. A data bank and a report bibliographic search was performed in May, 1969 and updated in June, 1970. A two level search strategy was used: level one - 1. integrated circuits, 2. microelectronics; level two - 1. circuit interconnections, 2. bonding, 3. bonded joints, 4. ultrasonic welding.
2. Bibliographic search by the Reliability Analysis Center, IIT Research Institute, 10 West 35th Street, Chicago, Illinois 60616. Performed in June 1969.
3. U. S. Patent search. Performed May, 1969.
4. Scientific and Technical Aerospace Reports for the years 1965-1970. Subject categories were: electronics, electronic equipment, and physics.
5. U. S. Government Research and Development Reports for at least the period from 1969-1970. Earlier entries would be included in item 1. Subject fields were electronic and electrical engineering, methods and equipment, and physics
6. Journals in Table 2 that are preceded by an asterisk. Issues of these journals published in the period from 1965 to 1970, inclusive, were examined.

TABLE 2. ABBREVIATIONS AND JOURNALS SEARCHED

AIME - American Institute of Mining, Metallurgical and Petroleum Engineers
 ASME - American Society of Mechanical Engineers
 ASTM - American Society for Testing and Materials
 ASTME - American Society of Tool and Manufacturing Engineers
 Appl. Phys. Lett. - Applied Physics Letters
 *Bell Lab. Rec. - Bell Laboratories Record
 *Bell System Technical Journal
 Brit. Commun. Electron. - British Communication and Electronics
 Brit. J. Appl. Phys. - British Journal of Applied Physics
 Circuits Mfg. - Circuits Manufacturing
 Conf. - Conference
 *EDN - (formerly Electrical Design News)
 *EE - (now, The Electronic Engineer; formerly, Electronic Industries)
 *EEE
 *Electron. Packag. Prod. - Electronic Packaging and Production
 *Electron. Prod. - Electronic Products Magazine
 *Electronic Design
 *Electronic Engineer - The Electronic Engineer (formerly EE, formerly Electronic Industries)
 *Electron. Lett. - Electronics Letters
 *Electronics
 *Electro-technol. - Electro-technology (New York)
 Eval. Eng. - Evaluation Engineering
 *IBM Journal of Research and Development
 IEEE - Institute of Electrical and Electronics Engineers (formerly IRE)
 IEEE Intern. Conv. Record - IEEE International Convention Record (formerly IRE . . .)
 *IEEE Trans. Electron Devices - IEEE Transactions on Electron Devices (formerly IRE . . .)
 *IEEE Trans. Nucl. Sci. - IEEE Transactions on Nuclear Science
 *IEEE Trans. Pts. Materials Packaging - IEEE Transactions on Parts, Materials and Packaging
 *IEEE Trans. Sonics Ultrason. - IEEE Transactions on Sonics and Ultrasonics
 *Industrial Research
 *International Journal of Nondestructive Testing
 Int. - International
 IEC - International Electrotechnical Commission
 IRE - Institute of Radio Engineers
 IRE Intern. Conv. Record - IRE International Convention Record
 IRE Trans. Electron Devices - IRE Transactions on Electron Devices
 J. Appl. Phys. - Journal of Applied Physics
 *J. Electrochem. Soc. - Journal of the Electrochemical Society
 J. Sci. Instrum. - Journal of Scientific Instruments
 Mater. Eval. - Materials Evaluation
 *Mater. Res. Std. - Materials Research and Standards
 Metals Eng. Quart. - Metals Engineering Quarterly
 *Microelectronics and Reliability
 Nat. Electron. Conf. - National Electronics Conference
 Mfg. - Manufacturing
 NEPCON - National Electronic Packaging and Production Conference
 Philips Tech. Rev. - Philips Technical Review
 Proc. IEEE - Proceedings of the Institute of Electrical and Electronics Engineers
 *Prod. Eng. - Product Engineering
 *RCA Review
 *Rev. Sci. Instr. - The Review of Scientific Instruments
 Rev. Elec. Commun. Lab. - Review of the Electrical Communications Laboratory, Tokyo. (Denki Tsushin Kenkyujo)
 SAE - Society of Automotive Engineers
 Semicond. Prod. - Semiconductor Products
 *Semicond. Prod. Solid State Technol. - Semiconductor Products . . . Solid State Technology Soc. - Society
 *Solid State Abstracts
 *Solid State Electron. - Solid State Electronics
 Solid State Technol. - Solid State Technology
 Symp. - Symposium
 Technol. - Technology
 *Trans. Met. Soc. AIME - Transactions of the Metallurgical Society of the AIME
 *Ultrasonics
 Welding J. - Welding Journal
 WESCON - Western Electric Show and Convention

*Journals searched completely for period 1965-1970.

TABLE 3. AVAILABILITY NOTES

- [1] U. S. Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120.
- [2] Publications Sales Department, The IEEE, 345 East 47th Street, New York, New York 10017.
- [3] American National Standards Institute, Inc., 1430 Broadway, New York, New York 10018.
- [4] Industrial and Scientific Conference Management, Inc., 222 West Adams Street, Chicago, Illinois 60606.
- (5) Uthe Technology, Inc., 670 Almanor Ave., Sunnyvale, California 94086.
- [6] Illinois Institute of Technology, Chicago, Illinois 60606.
- [7] ASME Order Dept., 345 47th Street, New York, New York 10017.
- [8] American Welding Society, 345 East 47th Street, New York, New York 10017.
- [9] Technology Utilization Division, NASA, Code UT, Washington, D. C. 20546.
- [10] Gordon and Breach, Science Publishers, Inc., New York, New York 10001.
- [11] ASTM, 1916 Race Street, Philadelphia, Pennsylvania 19103.
- (12) MIT Instrumentation Laboratories, Cambridge, Massachusetts 02142.
- (13) North American Aviation/Autonetics, Anaheim, California 92803.
- (14) Norden Division of United Aircraft Corp., Norwalk, Connecticut.
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- (16) Westinghouse Electric Corp., Baltimore, Maryland.
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- (19) Weldmatic Div., Unitek Corp., Monrovia, California.
- (20) Martin Marietta Corp., Quality Engineering Dept., Orlando, Florida.
- (21) Lockheed Missiles and Space Co., Lockheed Palo Alto Research Laboratories, Palo Alto, California 94304.
- [22] Sandia Labs., Albuquerque, New Mexico 87115.
- (23) Hughes Aircraft Co., Welder Dept., Oceanside, California 92054.
- (24) United Aircraft Corp., Electronic Components Div., Trevose, Pennsylvania.
- (25) Westinghouse Defense and Space, Mfg., Research and Development, Baltimore, Maryland.
- (26) McDonnell Douglas Astronautics Co., Western Div., Santa Monica, California.
- (27) RADC, Griffiss Air Force Base, Rome, New York 13440.
- (28) Fairchild Semiconductor, Research and Development Laboratories, Palo Alto, California 94304.
- (29) National Bureau of Standards, Washington, D. C. 20234.
- [30] Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.
- (31) Lockheed Missiles and Space Co., Sunnyvale, California.
- (32) Texas Instruments, Inc., Dallas, Texas 75222.
- (33) AC Electrics Div., General Motors Corp., Milwaukee, Wisconsin.
- (34) IBM Corp., Endicott, New York 13760.
- (35) Raytheon Co., Sudbury, Massachusetts 01776.
- (36) RCA, Somerville, New Jersey 08876.
- (37) Motorola Inc., Phoenix, Arizona 85008.
- (38) Delco Electronics Division, General Motors Corp., Milwaukee, Wisconsin.

Three levels of key words are used in the bibliography to indicate the subject material in the works compiled, each successive level being less broad in scope. To help identify key words of different levels, all the letters are capitalized for first-level key words while only the first letter of the second-level key words is capitalized. The third-level key words are all in lower-case.

First-level key words are used to indicate general subject areas discussed; they are TEST, FABRICATION, and DEGRADATION. One or more of these key words may be used, depending on the contents of the work. The order of listing is meant to indicate the relative emphasis given each area if more than one is listed.

The kind of wire bonds involved in the discussions of a given subject is described by a series of descriptors arranged on the same line and following the first-level key word describing the subject area. The descriptions that may be used, depending on what is discussed, are: bond, wire, film, thick film, substrate, and application. They refer, respectively, to the bond involved; the wire material; the metallization film(s) on the bonding surface or the material on which the wire is bonded if no metallization film is used; the thick-film ($> 1 \mu\text{m}$) conductive composition, if used; the substrate material under the conducting film; and the application or use of the wire bond in hybrid circuits or plastic devices. Following each of these descriptors are symbols or words to indicate the kinds of bonds, materials, and applications that are used or discussed. If the comments are of a general nature and no particular wire bond is mentioned in the entry then descriptors are not given.

If a test method is discussed in the context of testing or evaluating the wire bond then the first-level key word TEST is listed under the entry in the bibliography. As appropriate, one or more of the following second-level key words is listed below TEST: Description, Evaluation, Correlation, Application, Precautions, and Screening Procedures; in that order. The key words (third-level) for the test methods are arranged in alphabetical order after and on the same line with the appropriate second-level key words listed above. If the entry describes a test method in any detail, the key word for the method will follow Description; if it evaluates the methods the key word will follow Evaluation; if it presents correlation information with other methods for the same type of wire bond, then key words for these methods will follow Correlation. If the material in the entry is or may be applicable to a test method, its key word will follow Application, while if the material deals with precautions in the use of a method its key word will follow Precautions. Finally, if the material in the entry deals with procedures in which several tests are performed as a means of culling out weak wire bonds then Screening Procedures will be listed without an indication of the test methods involved.

If material in the entry deals with some as-

pect of the fabrication of wire bonds then the first-level key word FABRICATION is used. The second-level key words that have been selected are as follows: Theory, Evaluation, Procedure, Schedule, Variables, Apparatus, Control, Tool, Rigidity, Wire, Bonding Surface, Test, and Trouble Shooting. Without mentioning the third-level key words in any detail, the meaning and intent of the above listed second-level key words will now be indicated. The key word Theory relates to the theory of making a bond while Evaluation relates to the evaluation of such things as the type of bonding process, the type of bond, the metal systems used, etc. The key word Procedure refers to the procedures or steps in making a particular type of wire bond. The key word Schedule refers to the optimization of the fabrication processes and procedures for making wire bonds, while the key word Variables refers to the effects that specific variables have on the quality or strength of a wire bond. The key word Apparatus refers to the bonding machine and its accessories; Control refers to the importance of controlling specific parameters; Tool refers to the tool used to press against the wire while the bond is made; Rigidity refers, generally, to the importance of mechanical rigidity and positional control in the fabrication of the wire bond; Wire refers to the wire used; and Bonding Surface to the characteristics of the bonding surface pertinent to good bonding. If test methods are used to evaluate the fabrication procedures their key words are listed after Test. Finally, if the entry discusses hints or methods for locating and correcting deficiencies in the fabricating procedures, the key word Trouble Shooting will be used.

If material in the entry deals with some aspect of the degradation or failure of wire bonds then the first-level key word DEGRADATION is used. The second-level key words that have been selected are as follows: Stress, Part, Mechanism, Test, and Failure Rates. The third-level key words for the first three of these were selected to be more specific in terms of, respectively, (1) the kind of stress that produces a weakened wire bond as a result of the fabrication process or that results in degradation or failure of an already completed wire bond; (2) the part or component, primarily of the wire bond, that is or has been affected by the stress; and (3) the mechanism, if defined, that is involved in the degradation or failure. If a test method is used to detect or measure this degradation or failure then the key words of the test methods used will follow Test. If general reliability data, such as failure rates of specific kinds of wire bonds under specific conditions or stress, are included in the entry then the key word Failure Rates is used; third-level key words follow to indicate if the information pertains to thermocompression or ultrasonic wire-bonds, or if the kinds of wire bonds are not indicated.

The first-level key words used to indicate the approach or the type of the entry are ANALYTIC, DESCRIPTIVE, EXPERIMENTAL, and THEORETICAL; and PATENT, REVIEW, and STANDARD. Only one of these key words is used and it is listed last.

TABLE 4. TEST METHODS AND BRIEF DESCRIPTIONS

air blast A jet of gas, usually air or nitrogen, is directed at the wire.	pull (nondestructive) The wire is pulled by a probe to a predetermined tensile stress.
bond monitor Some measure of the mechanical coupling between the tool, wire, and metal film is monitored during ultrasonic bonding.	radiotracer Radiotracers are used to detect the distribution of contaminants and to study interfacial displacements.
centrifuge A constant centrifugal force is applied to the device.	resistance The contact or bond-interface resistance is measured (directly or indirectly).
electrical parameter A device performance test is used to determine device degradation caused in some way by the wire bond.	temperature cycle The device is exposed alternately between two temperature extremes to test the ability of the wire bond to sustain the mechanical stresses that result from differences in the thermal coefficients-of-expansion of the constituent parts.
electron microprobe An electron microprobe is used to identify contaminants in the wire bond.	thermal shock Same as temperature cycle except that the transfer time between temperature extremes is shorter.
IR monitor The infrared radiation from a bond is used to obtain a measure of the thermal resistance of the bond interface and hence the area of contact and the quality of the bond of the wire to the bonding surface.	US probe Ultrasonic energy is used to test (probe) the mechanical quality of bonds.
interferometry The motion of ultrasonic bonding tools and velocity transformers in ultrasonic bonding machines is studied with use of interferometry.	US stress Ultrasonic energy is used to stress wire bonds.
mechanical shock A large, short-duration deceleration is applied to the device.	vibration (fatigue) The device is vibrated at a fixed frequency for long periods of time at a relatively low maximum acceleration level.
mechanical shock (radiation-induced) The absorption of a short pulse of high-energy electrons in a plate fastened to the base of the device header is used to generate thermally-induced stress waves which are used to stress the wire bond.	vibration (monitored) The electrical parameters of the device are monitored while it is being vibrated.
metallurgical exam The structure and interface of wire bonds are examined metallurgically.	vibration (variable frequency) The device is vibrated thru a frequency range at a relatively constant, maximum acceleration.
Mil-Std-750B Military standard test methods for discrete devices.	visual inspection Wire bonds are examined under a microscope to determine if they conform to predetermined criteria of physical appearance, location, and orientation.
Mil-Std-883 Military standard test methods for integrated circuits.	visual inspection (SEM) The same as the visual inspection test except a scanning electron microscope (SEM) is used.
noise Electrical noise measurements are used to detect abnormalities in the wire bond.	x-ray exam X-rays are used to look for abnormalities in wire routing and orientation in encapsulated devices.
photoelastic stress analysis Stress distributions in the vicinity of the bond are studied.	
pull The wire is pulled by a probe, usually hook-like, until some part of the wire bond ruptures.	

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